Chem. Lib
540.5
I58
P49

VOL. 5. JUNE, 1919. NO. 20.

JOURNAL

OF

THE INSTITUTION

OF

PETROLEUM TECHNOLOGISTS

AND

RECORD OF TRANSACTIONS.

FOUNDED 1913—INCORPORATED 1914.

PUBLISHED BY
THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.
17, GRACECHURCH STREET, E.C.,
AND PRINTED BY
CROWTHER & GOODMAN, LIMITED,
154, FENCHURCH STREET, LONDON, E.C.

PRICE 5s. 0D.

All rights of Publication or Translation are reserved.

MODERN REFINERY WORK.

COMPLETE PLANTS - AND MACHINERY -

SUPPLIED FOR

Acid Pumping by New Method.
Asphalt Distilling.
Benzine, Kerosine and Lubricating Oil Washing.
Benzol Recovery.
Continuous Benzine Rectification.
Continuous Crude Oil Distillation.
Continuous Residue Distillation.
Continuous Vacuum Oil Distillation for Lubricating & Vacuum Oils.
Continuous Petrol Washing.
Cracking and Coking Distilling.
Debenzination of Crude Oil.
Lignite Distillation.
Paraffin Extraction and Refining.
Petrol Rectifying.
Pumping Installations.
Shale Distillation.
Sulphuric Acid Recovery.
Uncondensable Gas Plant and Benzine Enrichment.
Vacuum Continuous Lubricating Oil Distillation.

Stills, Retorts, Superheaters, and Montejus for all Purposes.

NEW PLANTS DESIGNED TO SUIT SPECIAL REQUIREMENTS.

WRITE FOR PAMPHLET ON MINERAL OIL DISTILLATION.

W. J. FRASER & CO., LTD.,

ENGINEERING WORKS,

DAGENHAM, ROMFORD, ESSEX.

Telegrams:
"FRASER, DAGENHAM."

Telephone:
222 ROMFORD (2 lines).

LIST OF THE OFFICERS

OF

The Institution of Petroleum Technologists, 1919—1920.

Past Presidents:

† Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. (1914-1916).
Prof. Sir John Cadman, K.C.M.G., D.Sc., M.Inst.C.E. (1916-1917).
Sir Charles Greenway, Bart., 1917–1919.

President:

Sir Frederick W. Black, K.C.B., B.A. (Lond.)

Vice-Presidents:

Prof. Sir John Cadman, K.C.M.G., D.Sc., M.Inst.C.E.
The Rt. Hon. Viscount Cowdray of Cowdray.
Sir Charles Greenway, Bart.
Sir Thomas H. Holland, K.C.I.E., D.Sc., F.R.S.

Members of Council:

Alfred C. Adams.
Herbert Allen.
Capt. R. W. Barnett, M.P.
Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A.
Sir George Beilby, LL.D., F.R.S.
Edwin R. Blundstone, B.A., F.C.S.
Prof. J. S. S. Brame, F.I.C., F.C.S.
Andrew Campbell.
John T. Cargill.
E. H. Cunningham Craig, B.A., F.R.S.E., F.G.S.
A. E. Dunstan, D.Sc., F.C.S.
Arthur W. Eastlake, M.I.Min.E., A.M.I.Mech.E.
W. R. Ormandy, D.Sc., F.C.S.
T. C. Palmer, Assoc.M.Inst.C.E.
F. Mollwo Perkin, Ph.D., F.I.C., F.C.S.
Robert Redwood, F.C.S.

Honorary Treasurer: Sir William Plender, G.B.E.

Honorary Solicitors: Messrs. Ashurst, Morris & Crisp.

Honorary Auditors: Messrs. Price, Waterhouse & Co.

Bankers:

London County Westminster and Parr's Bank Limited,
21, Lombard Street, London, E.C. 3.

Hon. Editor and Librarian:

W. H. Dalton, F.G.S., F.C.S.

Hon. Secretary:

Arthur W. Eastlake, M.I.Min.E., A.M.I.Mech.E.
Offices. 17, Gracechurch Street, London, E.C. 3.

† Deceased.

COMMITTEES.

ELECTION, FINANCE AND PUBLICATION.

Members of the Election Committee.

Sir GEORGE BEILBY, LL.D., F.R.S.
EDWIN R. BLUNDSTONE, B.A., F.C.S.
Prof. Sir JOHN CADMAN, K.C.M.G., D.Sc., M.Inst.C.E.
ANDREW CAMPBELL.
ARTHUR W. EASTLAKE, M.I.Min.E., A.M.I.Mech.E.
Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.
T. C. PALMER, Assoc.M.Inst.C.E.
Sir FREDERICK W. BLACK, K.C.B., B.A. (Lond.) (*ex officio*).

Members of the Finance Committee.

ALFRED C. ADAMS (*Chairman*).
ARTHUR W. EASTLAKE, M.I.Min.E., A.M.I.Mech.E.
T. C. PALMER, Assoc.M.Inst.C.E.
ROBERT REDWOOD, F.C.S.
Sir FREDERICK W. BLACK, K.C.B., B.A. (Lond.) (*ex officio*).

Members of the Publication Committee.

Sir GEORGE BEILBY, LL.D., F.R.S.
EDWIN R. BLUNDSTONE, B.A., F.C.S.
Prof. J. S. S. BRAME, F.I.C., F.C.S.
Prof. Sir JOHN CADMAN, K.C.M.G., D.Sc., M.Inst.C.E.
A. E. DUNSTAN, D.Sc., F.C.S.
Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S.
W. R. ORMANDY, D.Sc., F.C.S.
F. MOLLWO PERKIN, Ph.D., F.I.C., F.C.S.
Sir FREDERICK W. BLACK, K.C.B., B.A. (Lond.) (*ex officio*).

CONTENTS.

PAGE

Council and Officers i

Committees ii

General Notices:—

Copyright iv

Issue of Journal iv

Changes of Address iv

To Authors of Papers iv

Advertisements in the Journal v

List of Advertisers v

Personal Notes of Members and Special Notices vi

The late Sir Boverton Redwood, by the Hon. Editor ... 241

Thirty-eighth General Meeting, 15th April, 1919:—

Valedictory Address by the retiring President, Mr. C. Greenway 249

Presidential Address (Some War Problems of Petroleum Supply), by Sir F. W. Black, K.C.B., B.A. (Lond.) 251

Thirty-ninth General Meeting, 20th May, 1919:—

Paper: The Chemist and Engineer in Relation to the Petroleum Industry, by F. M. Perkin, Ph.D., F.I.C., F.C.S., and T. C. Palmer, Assoc.M.Inst.Civ.Eng. ... 285

Discussion: by the President, Sir Boverton Redwood, Prof. J. W. Hinchley, Dr. W. T. Ormandy, Messrs. H. V. Mitchell, A. J. Wilson, N. A. Anfilogoff and Gathorne Young 294

Later Communication from Mr. H. V. Mitchell ... 309

NOTICES.

The Institution as a body is not responsible for the statements or opinions expressed in any of its publications.

Copyright. The entire contents of the Journal are covered by general copyright, and official permission is necessary for reprinting long abstracts; but editors may use not more than three pages of any paper, provided that credit is given as reproduced from the Journal of The Institution of Petroleum Technologists or advance-proofs thereof.

Issue of Journal. The Journal appears in four parts per sessional volume, viz. in December, February, April and June. A brochure describing the origin, progress and purposes of the Institution, and comprising also the Memorandum and Articles of Association, the By-Laws and Regulations of the Institution, the Library Catalogue to date (with subject index), and the List of Members, was published in September, 1915, to be followed annually by revisions of the Library Catalogue and List of Members.

Members of all classes are entitled to receive these publications free: for additional copies of the Journal they will be charged at the price of five shillings per part, and of the brochures at the prices stated on the wrappers, varying in proportion to bulk.

Changes of Address. It is particularly requested that members notify the Secretary immediately of any change of address; and members are also requested to advise the Parcel-Post Department as well as the Letter Office, of any temporary change of address, as, unless this is done, parcel-post packets will not be re-addressed; but will be returned to the offices of the Institution in London, thus incurring further expense for postage.

To Authors of Papers. Papers should be written in the third person, and the copy should be carefully corrected by the author before it is presented.

All drawings, diagrams or other illustrations should be sent in a fit state for direct photographic reproduction.

All quotations, technical terms, and localisms should be indicated by means of inverted commas.

Foreign weights, measures, and costs should be given whenever possible: and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case the exact reference to the previous publication should be given.

Communications upon papers read at meetings, notices of personal movements, or other matter for which publication is desired in the next issue of the Journal, should be in the hands of the Editor on or before the last day of January, March, May or November as the case may be. Subsequent delivery may be too late for insertion.

Advertisements in the Journal. A limited number of Advertisements of firms interested in the Petroleum Industry may be inserted in the Journal. Application for terms, etc., should be made to the Secretary.

LIST OF ADVERTISERS.

(Members are desired, when making enquiries or placing orders with advertisers, to mention that they have seen their announcement in the Journal.)

ANGLO-MEXICAN PETROLEUM CO., LTD.
W. CHRISTIE & GREY, LTD.
W. J. FRASER & CO., LTD.
HAYWARD-TYLER & CO., LTD.
LIBRACO, LTD.
LUCEY MANUFACTURING CORPORATION.
OIL WELL SUPPLY CO.
W. H. WILLCOX & CO., LTD.

PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

Mr. C. Barrington Brown has left for South America.

Lieut. F. D. Brown is at home on leave.

Mr. G. W. Lepper, of the Geological Staff of the Burmah Oil Co., Ltd., is home on leave.

Mr. F. W. Moon has returned from Egypt on leave.

2nd Lieut. F. G. Rappoport has been promoted to Captain in the Indian Army Reserve Officers, attached to the R.E.

Mr. C. B. Rosenplaenter has returned from Algeria.

Mr. R. J. Ward has left for Yenangyoung, Upper Burma.

Mr. Kenneth Watts has been demobilised from the American Tank Corps, and has returned to the United States. He is now at Tulsa, Oklahoma.

EDITORIAL.

The late Sir Boverton Redwood.

The inexorable Distiller, whose function is the separation of human spirits from the grosser substances in which they are enwrapped, has taken from amongst us one of the greatest of authorities on the vast subject of petroleum.

His wide-ranging experience and keen perspicacity, enabling him to take into simultaneous cognisance the multitudinous factors affecting even the apparently most simple of problems, rendered his decisions of supreme value to his clients, and through them, it may in all verity be asserted, to the community at large, since all, producers and consumers alike, derive benefit from the judicious exploitation of natural resources, and the direction of energy in advantageous directions. Sir Boverton's extreme versatility would be well illustrated by the record of a single day's interviews, sometimes of but a few minutes' duration, though only his secretary could realise the extreme diversity of topics handled in such rapid succession.

But his transcendent mental endowments were perhaps the less immediately appreciated, from the personal feelings evoked by his ready and courteous sympathy with any difficulty presented by his consultants, so that the guide and philosopher almost instantly merged in the friend, and in numerous cases of prolonged acquaintance, friendship ripened into affection.

We have therefore to regret the loss, not merely of the sage counsellor and oracle of information, but of the trusty and well-loved brother or father, as relative ages might determine with seniors and juniors respectively: for the former the loss is irreparable, though the rising generation may find some approximate substitute in the course of time.

Born on the 26th April, 1846, at 19, Montague Street, Russell Square, within sight of the original British Museum, then largely devoted to Natural Science, he was the eldest son of Dr. Theophilus Redwood, of Boverton, Glamorganshire, who held for forty years the professorship of Pharmacy in the Pharmaceutical Society, and was so keenly interested in his life pursuit that it was frequently necessary to send a messenger to the Society's laboratories in Bloomsbury Square to remind him of the recurrence of family meal times. In this atmosphere, strongly imbued at times with organic elements of more recent origin than those of his later

investigations, the rising expert received his earliest impulse in the direction of chemistry whilst studying in University College School, and became a Fellow of the Chemical Society in January, 1866, i.e. before reaching the age of 20.

In 1869 he was appointed Secretary to the Petroleum Association, and definitely selected Mineral Oil as the main basis of his lifework, in face of the deprecation of some shorter-sighted friends, who regarded his choice as too narrow a subject for a professional career. It has by later development become too wide for any but the most colossal of intellects, average minds finding their limit in minor subdivisions.

His earliest work was in connection with the testing of the flash-point of mineral oils. In 1872 he gave evidence on the subject before a Select Committee of the House of Lords, and in 1876–77 he was called to advise as to legislation, carrying out experimental researches in conjunction with Sir Frederick Abel, which resulted in the establishment of the Abel apparatus as the standard method of testing. He visited the United States in 1877 in extension of the same line of investigation.

The effect of barometric pressure on the evolution of volatile constituents of oil was a cognate factor which he studied in 1881 at various altitudes in the Alps and in a pressure-chamber at Berlin, and in the following year he visited India to investigate the influence of climatal conditions, carrying out on his return a series of experiments in conjunction with Sir F. Abel and Dr. Kellner, on the basis of which he advised the Government of India in amending the Petroleum Act, and designed a modification of the Abel instrument to meet the case of oils which excess of paraffin wax rendered solid at ordinary temperatures, provision for which contingency was made in subsequent legislation. In this connection it may be mentioned that the name motorine, applied to a viscid lubricant, was once misunderstood to imply motor-spirit, and the consignors were called upon to declare its flashpoint.

His evidence was again called for by a Select Committee of the House of Lords in 1883, in which year he accompanied Sir Vivian Majendie on an exhaustive inspection of the petroleum industry in the British Islands and principal countries of Europe, and in 1886 in the United States and Canada.

Then, turning attention upon the viscosity of lubricating oils, he designed in 1886 the Redwood viscometer, accepted as a standard by the British Government, by the great carrying companies by land and sea, and by chemists and the trade generally, whilst a later modification for testing fuel oil was endorsed by the Admiralty.

A few years later, again in co-operation with Sir F. Abel, he investigated the cause of accidents with lamps using mineral oil, and draughted directions as to their construction and use. Methods of determination of the quality of lamp-oils and lamp-wicks were also designed.

In 1892 the question of the transport of oil in bulk through the Suez Canal involved a visit to Egypt, and he reported the result, in conjunction with Sir F. Abel. In this and the following year he studied the problem offered by the accumulation of petroleum vapour in the tanks and other less accessible parts of ships carrying such cargoes, and the explosions resulting by the access of flame, or even hot rivets, to such unsuspected sources of danger. The apparatus he designed for testing the presence of such vapour has been in constant application since his account of the matter in 1894, for which the Institution of Civil Engineers awarded him the Telford premium.

The Redwood water-finder for determining the amount of water which may have collected under the oil in a tank was devised by Boverton Redwood in 1893, in conjunction with his brother Robert and Mr. H. Barringer, and is in very general use.

In the collateral subject of acetylene he was an active member of the Society of Arts Committee for the exhibition of acetylene generators at the Imperial Institute in 1899. His strong interest in the utilisation of petroleum, either as liquid fuel for raising steam, or the more direct source of energy by explosive combustion, drew his attention to motor cars, and it is more than 20 years since the first 4-cylinder Daimler car was constructed to his order in this country, and by permission exhibited to the Prince of Wales, afterwards King Edward VII. From personal to commercial traction was a natural sequence of study, and he was one of the judges of the trials of heavy motor-wagons at Liverpool inaugurated by the Self-propelled Traffic Association in 1898–1901.

His presidency of the Finchley Cycling Club, his activities on the Committee of the Automobile Club of Great Britain, and his membership of the Automobile Club of France, further attested his interest in terrestrial movement, whilst his taste for the sea was almost equally pronounced, and a succession of vessels owned his proprietorship as a member of the Royal Thames Yacht Club. Of social clubs honoured by his membership may be named the Savage, the City of London, and the Constitutional. He was also a Warden of the Worshipful Company of Goldsmiths.

For many years he acted as honorary technical adviser to the Admiralty, the Colonial, Home and India Offices, the Corporation

of London, the Port of London Authority, the Thames Conservancy and other official bodies.

In 1904 he gave evidence before the Royal Commission on Coal Supplies on the use of liquid and solidified petroleum on ships and as domestic fuel, and on alcohol as a substitute for petrol in internal-combustion engines. Later he served on Lord Fisher's Royal Commission on Fuel and Engines, and on that on Food and Raw Materials in Time of War. He was chairman of the Gas Traction Committee from 1917, of the Interdepartmental Committee on Industrial Alcohol, and of the Conference of the Inter-Allied Commission on Petroleum Storage in France, 1918.

Professionally he was consulted on the occurrence, real or supposed, of petroleum in nearly every part of the world, and deservedly trusted by clients whose interests sometimes verged upon antagonism, when, without betraying any confidential information, he would impartially advise procedure consonant with his grasp of the whole situation—occurrence, quality, manipulation, transport and market, whilst minor points in every branch were continually brought for his decision.

In many public exhibitions he was called upon to assist on the committees of management of sections including uses of petroleum. In those of Brussels, Rome, Turin, and St. Louis, he was Royal Commissioner: in the Inventions, Health, Franco-British and Japan-British he was one of the leading Members of Committee.

Besides the publications enumerated below, he assisted in the establishment of curricula devoted to petroleum at Birmingham University and the Imperial College of Science, and far from attempting to exclude the crowd from penetrating into the arcana of science, he did much to popularise the knowledge of at least its elements.

His connections with scientific societies were so numerous and varied, that an alphabetical arrangement seems preferable to chronological sequence of the overlapping functions involved.

American Philosophical Society, Hon. Member.
British Science Guild, Executive Committee, Deputy-Chairman.
Chemical Society, Council twice.
City and Guilds of London Institute, Executive Committee and Technology Committee.
Geological Society.
Imperial Russian Technical Society, Hon. Member.
Institute of Chemistry, Council, Vice-President.
Institute of Metals.

Institute of Mining Engineers.
Institution of Civil Engineers.
International Congress on Applied Chemistry, Executive 1909.
Junior Institution of Engineers, President 1913–1914.
National Physical Laboratory, General Board.
Ohio Normal University, Hon. D.Sc.
Royal Geographical Society.
Royal Institution, Board of Visitors.
Royal Society of Arts, Vice-President, Committee on Acetylene generators.
Royal Society of Edinburgh.
Society of Chemical Industry, Council, Publication Committee, Chairman of London Section, President 1907–1908.
Society of Public Analysts, Council.

His services to this Institution need not be recapitulated here. A leading spirit from its very foundation, and its President for two years, he continued to render valued assistance to the last, though his services to the country occupied the greater part of his time after the commencement of the war. He first served on various Government Committees, was appointed Assistant Controller in Trench Warfare Research in 1916, was selected as Director of Petroleum Research under the Ministry of Munitions in 1917, and then transferred as Director of Technical Investigations to the Petroleum Executive, besides the other official functions already mentioned. He was knighted in 1905, and received a baronetcy in 1911. The title passes to the grandson, Thomas Boverton Redwood, now 13 years of age. Lady Redwood was the eldest daughter of Mr. Frederick Letchford, and has two daughters living, her son Bernard Boverton Redwood, the father of the new baronet, having died in 1911.

He laboured in his vocation to the last. Even on the 2nd of June, though already suffering from the chill that was destined to prove fatal within 48 hours, he telephoned to the Executive, by Lady Redwood's voice, a final message as to the sulphur content of the oil lately found in Derbyshire.

The last sad rites were performed at Hampstead Cemetery on the 7th June, in the presence of a great number of sorrowing friends, the Institution being officially represented by the President, Sir Frederick W. Black, K.C.B., and Mr. Arthur W. Eastlake, whilst among the Members present were Mr. A. C. Adams, Mr. J. T. Cargill, Mr. T. C. Palmer, Dr. F. Mollwo Perkin, and Mr. Robert Redwood (Members of Council), and Dr. M. B. Blackler, Mr. A. G. V. Berry, Mr. Ashley Carter, Major A. Cooper-Key, Lieut. A. Lloyd

Eastlake, Mr. J. Arthur Greene, Mr. E. Lawson Lomax, Mr. H. V. Mitchell, Mr. H. E. Nichols, Mr. Maurice A. Ockenden, Mr. C. B. Rosenplaenter, and Mr. William Sutton.

Sir Charles Greenway wrote to express his deep regret that the very precarious state of his health precluded his presence at the funeral of his old friend, and to convey his sympathy with the Institution in its heavy loss.

So has passed away the brilliant scientist, the careful investigator, the sound adviser, the sympathetic friend, usefully occupied to the very close of his long and honourable career. May his example stimulate many to follow in his footsteps, at however great an interval.

List of Works of Sir Boverton Redwood.

Redwood, B. New Reading of the Petroleum Acts. *Pharm. Journ.*, ser. 3, vol. i, pp. 1025, 1026. 1871.

———— The Estimation of Colour in Liquids. *Ibid.*, vol. ii, pp. 342–344. 1871.

———— [Evidence before the Select Committee of the House of Lords on the Petroleum Bill, 1872]. Pp. 37–55, 154, 155.

———— Testing Paraffin Oil—Explosion of Lamps. *Engl. Mech.*, vol. xxii, pp. 355, 376, 458. 1875, 1876.

———— Description of Mr. R. P. Wilson's Chrono-Thermometer, for use in testing Mineral Oils. *Ibid.*, p. 496. 1876.

———— The Secretary's Report of his Mission to the United States and Canada. Pp. 40. 8vo, *London*, 1878.

———— Life in the more recently developed Oil-fields of the United States. *Pharm. Journ. Trans.*, vol. xxxviii, pp. 753–755. 1879.

———— Report of a Special General Meeting of the Members of the Petroleum Association and those Engaged in the Trade . . . August 8th, 1883 [*re* Petroleum Bill]. Pp. 32. 8vo, *London*, 1883.

———— The Petroleum Production Company. Nobel Brothers, Limited, St. Petersburg. Pp. 13. 8vo, *London*, 1883.

———— [Evidence before the Select Committee of the House of Lords on the Petroleum Bill, 1883]. Pp. 32–45.

Abel, F. A., and B. Redwood. Note on the Employment of the Abel Petroleum Testing Apparatus in Tropical Climates. *Chem. News*, vol. xlix, pp. 196, 197. 1884.

Redwood, B. The Determination of the Percentage of Oil in Paraffin Scale. *Journ. Soc. Chem. Ind.*, vol. iii, pp. 430–432. 1884.

———— The Russian Petroleum Industry. *Ibid.*, vol. iv, pp. 70–81, pl. 1885.

———— Petroleum and its Products. *Cantor Lectures*, vol. iii, 1886.

———— On Viscosimetry, or Viscometry. *Journ. Soc. Chem. Ind.*, vol. v, pp. 121–133. 1886.

Abel, F. A., and B. Redwood. On Petroleum Lamps and their Danger. *Daily News*, September 22, 1886; *Polyt. Journ.*, bd. cclxii, pp. 416–418. 1886.

REDWOOD, B. Notes of a Recent Visit to some of the Petroleum Producing Territories of the United States and Canada. *Journ. Soc. Chem. Ind.*, vol. vi, pp. 405–412. 1887.

———— Petroleum, its production and use. 12mo, *New York*, 1887. [Published without authority from the author.]

———— Petroleum and Turpentine in C. E. Groves and W. Thorp's Chemical Technology. 8vo, *London*, 1889. Ed. ii, 1895.

ABEL, F. A., and B. REDWOOD. Suggestions in Reference to the Construction and Use of Mineral Oil Lamps. Leaflet. n.d. (1889).

——, —— Accidents with Mineral Oil Lamps. Report to Home Office by Col. V. D. Majendie. Pp. 12. fo, *London*, 1890.

REDWOOD, B. The Oil-Fields of India: Notes on the Petroleum Deposits of Burma, Assam, the Punjab, and Baluchistan. *Journ. Soc. Chem. Ind.*, vol. ix, pp. 359–370. 1890.

———— Report to the Petroleum Defence Committee on the Home Office Memorandum of 25th March, 1891, relative to the Inflammable Liquids Bill. 1891.

———— The Galician Petroleum and Ozokerite Industries. *Journ. Soc. Chem. Ind.*, vol. xi, pp. 93–119. 1892.

———— Petroleum and Petroleum Testing in Sir E. Thorpe's Dictionary of Applied Chemistry. 8vo, *London*, 1893. Ed. ii, 1912, 1913.

———— The Transport of Petroleum in Bulk. *Proc. Inst. Civ. Eng.*, vol. cxvi, pp. 177–259, pls. vi–ix. 1894.

———— Report on India Rubber Solution, Appended to Instructions to Principal and Other Detaining and Emigration Officers. Board of Trade Marine Dept., no. 1240. May, 1894.

———— Petroleum: a Treatise on the Geographical Distribution and Geological Occurrence of Petroleum and Natural Gas; The Physical and Chemical Properties, Production, and Refining of Petroleum and Ozokerite; the Characters and Uses, Testing, Transport, and Storage of Petroleum Products, and the Legislative Enactments relating thereto; together with a Description of the Shale Oil and Allied Industries. Pp. xxvii, 900. 8vo, *London*, 1896. Ed. ii, pp. xxxii, 1064; 28 pls. 1906. Ed. iii, pp. xxxii, 367; 417; 383; 29 pls. 1913.

———— [Evidence before the Select Committee of the House of Commons on Petroleum, 1894–1896]. Pp. 92–177. 1898.

CLOWES, F., and B. REDWOOD. The Detection and Measurement of Inflammable Gas and Vapour in the Air. 8vo, *London*, 1896.

REDWOOD, B. The Petroleum Sources of the British Empire. *Coll. Guard.*, vol. lxxv, 204, 205, 658. 1898.

———— Report on Petroleum Fields of Assam. *Petr. Rev.*, vol. i, pp. 201, 202, 238, 239. 1899.

———— Report on the Petroleum Lands of Galicia. *Ibid.*, pp. 203, 204, 237, 238. 1899.

———— Uniformity in Methods of Testing Petroleum and its products. 1*st Internat. Petrol. Congr.*, pp. 31–33. 1900.

THOMSON, J. H., and B. REDWOOD. Handbook on Petroleum for Inspectors under the Petroleum Acts, and for those engaged in the storage, transport, distribution and industrial use of Petroleum and its Products, and Calcium Carbide; with suggestions on the construction and use of Mineral Oil Lamps. 8vo, *London*, 1901. Ed. ii, 1906; Ed. iii, 1913.

——, —— The Petroleum Lamp, its choice and use. A Guide to the safe

employment of Mineral Oil in what is commonly termed the Paraffin Lamp. 8vo, *London*, 1902. Ed. ii, 1908.

REDWOOD, B. Petroleum. Encyclopedia Britannica. Supplement. 4to, *London*, 1902.

——— [Evidence on Possible Substitutes for Coal for Production of Heat and Power: Alcohol, Use of Liquid and Solidified Petroleum on Ships and as Domestic Fuel] Second Report of Royal Commission on Fuel Supply, pp. 190–214: Summary in Final Report, pp. 15, 16. fo, *London*, 1904, 1905.

——— Report on a Sample of N'hangellite from Inhambane, Portuguese East Africa. *Bull. R. Bot. Gardens, Kew*, 1907, pp. 151–153.

——— Presidential Address. *Journ. Soc. Chem. Ind.*, vol. xxvii, pp. 779–788. 1908.

——— Present and Prospective Supplies of Petroleum and Shale Oil available for use as a Source of Power. Pp. 7–14 of Natural Sources of Energy (British Science Guild). 8vo, *London*, n.d. [1911].

——— The Future of Oil Fuel. *Journ. Soc. Arts*, vol. lxii, pp. 103–116. 1913.

REDWOOD, B., and V. B. LEWES. Petrol Substitutes for Use in Motor Vehicles. *Petroleum World*, vol. x, pp. 477–479. 1913.

REDWOOD, B. The Future of Oil Fuel. *Journ. Junior Inst. Eng.*, vol. xxiv, pp. 190–224. 1914.

——— Presidential Address. *Journ. Inst. Petr. Technol.*, vol. i, pp. 9–12. 1914.

REDWOOD, B., and A. W. EASTLAKE. The Petroleum Technologist's Pocketbook. Pp. 454. 32mo, *London*, 1915.

REDWOOD, B. Valedictory Address. *Journ. Inst. Petrol. Technol.*, vol. ii, pp. 192–195. 1916.

——— The Romance of Petroleum. *Journ. Roy. Inst.* 1918.

Thirty-Eighth General Meeting.

This Meeting was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday, 15th April, 1918, Sir Boverton Redwood, Bart., occupying the Chair.

The Members of Council present were Prof. J. S. S. Brame, Dr. A. E. Dunstan, Messrs. Arthur W. Eastlake, T. C. Palmer and Robert Redwood. A letter of regret for unavoidable absence was received from Dr. W. R. Ormandy.

The Chairman, in opening the meeting, said that an hour previously he had received with regret, which he knew would be shared by all the members, the following letter from the President, Mr. Charles Greenway :—" I have been laid up with fever for the past three days, and regret very much that my doctor will not let me risk attending to-day's meeting. This is a great disappointment to me, both because I should have liked to hand over the Chair personally to Sir Frederick, and also because I very much wished to hear his Presidential Address read, but in the circumstances there was no alternative." The President wished him in those circumstances to take his place, and to read the valedictory address which he would personally have delivered had he been present. Before doing so he was sure he would be voicing the wishes of all the members in recording an expression of their sympathy with Mr. Greenway in his illness, and their hope that he would very shortly be restored to health. The Chairman then read the following :

Valedictory Address by the retiring President :—

In addressing you for the last time from this Chair, I should like to express the great pleasure which it has given me to fill during the past two years the honourable position of President of your Institution. This pleasure has, however, been a good deal minimised by my consciousness of the very little which, mainly owing to the war conditions which have prevailed during my period of office, I have been able to do in the direction of promoting the welfare and objects of the Institution. The Institution has, as we all know, enormous scope before it in the direction of encouraging the education and training of petroleum experts of all kinds—geologists, chemists, oil engineers and drillers—particularly now that it has been recognised that petroleum is a national necessity, and that so much more British capital is being employed in its

production, refining and marketing. But, hitherto the development of the Institution has been seriously restricted by the smallness of its income, and now that the war is over I would suggest that we should venture on a little reconstruction of our own, and consider what steps can be taken in order to revise the income to a figure more commensurate with our requirements. It is obvious that we cannot go on accepting to so large an extent voluntary assistance from Sir Boverton Redwood, Mr. Arthur W. Eastlake and the other gentlemen who have been giving the Institution the benefit of their services, and it is also obvious that if we are to be dependent eventually upon the subscriptions of ordinary members, the funds available will not suffice for the larger offices and paid staff which are necessary for carrying on the work of the Institution in its entirety. I therefore venture to propose that a special membership should be created for Oil Companies at an annual subscription of say two hundred and fifty guineas per annum for each Company, and that all the leading Oil Companies should be invited to membership. I have discussed this proposal with one or two other Companies, and I feel sure that, now that the useful work which has already been done by the Institution is more generally recognised, there will be no difficulty in securing in this way the additional funds required for properly carrying on the very useful work of the Institution.

In resigning the Chair it is a matter of the greatest satisfaction to me that I am to be succeeded by a gentleman of so great distinction and ability as Sir Frederick Black. I have had the pleasure of knowing Sir Frederick since, I think, the year 1905, when I was first brought into contact with him in connection with oil matters during the time that Lord Fisher was First Lord of the Admiralty. Ever since that time he has been handling oil matters of every kind, as you will no doubt be able to judge from the paper which he is about to read, and I think that we are to be congratulated on having secured the services of so able and distinguished a Chairman.

The President (**Sir Frederick W. Black, K.C.B.**) before reading his Address, said he desired to join in the regret which Sir Boverton had expressed in regard to the cause of Mr. Greenway's absence, and through the Chairman to thank Mr. Greenway for the more than kind things he had said with regard to himself. He then delivered the following Address :—

Some War Problems of Petroleum Supply.

An address delivered to the Institution of Petroleum Technologists in London on 15th April, 1919, by the President of the Institution, Sir Frederick Black, K.C.B.

I regard it as a very great honour to be elected as President of the Institution of Petroleum Technologists. In accepting that honour I informed your Hon. Secretary that I was much alive to my shortcomings. I can, however, assure you of this, that throughout a long official career my heart has always been with the men who are doing their part in the practical work of the world. In particular it has been my good fortune to be associated for upwards of thirty years with great numbers of the Officers of His Majesty's Navy, the Technical Officers of the Admiralty, and recently with the Ministry of Munitions, also with business firms and manufacturers in this country and America, and with most of the great oil Companies of the world. Nor do I find myself among strangers in the company of members of the Institution of Petroleum Technologists.

At this point I would say a few words in regard to the three distinguished men who have preceded me in the office of President of your Institution, although I cannot claim to be fully qualified to appraise their merits. The founder of your Institution and first President was Sir Boverton Redwood, Bart., your second President was Sir John Cadman, K.C.M.G., and your third, Mr. Charles Greenway.* I need hardly say of Sir Boverton that he is steeped in the lore of his profession to the very finger-tips, and that his knowledge has been acquired in many fields by the application of great ability and powers of observation. His soundness of judgment is known to all of us. He has been to many of you, as he has been to me, a good friend and a wise and sagacious counsellor. For many years he has given his services as an honorary adviser to several Government Departments. I have long known him in particular as adviser to the Admiralty, and am able to speak of the high appreciation in which his services have been held. It would be difficult to recount what he has done in so many capacities for the service of his country during the war, not only in his own special sphere as an expert in petroleum matters, but by virtue also of his general scientific knowledge. It did not surprise me to find him helping the Ministry of Munitions in such matters as gas and flame production, but it was a revelation to me that he

* Now (April 29, 1919) Sir Charles Greenway, Bart.

knew so much about tungsten and other materials which came into the first rank of importance in the war. More recently I have found him full of knowledge on alcohol, for strictly industrial purposes.

I made Sir John Cadman's acquaintance some years ago in connection with his work for the Colonial Office. His services in respect to Trinidad in particular have been specially fruitful. During the war he actively assisted the Ministry of Munitions in the home production of oil, and has now been for a long time the head of the Petroleum Executive, under Mr. Walter Long. When I was in America I was in almost daily communication with him, and even at the other end of the cable I could see how order and efficiency were being established in the most difficult task of gauging and co-ordinating the petroleum requirements of the Allies. Since my return to England I have been in close association with him, and am indebted to him personally for great kindness and help. The great ability he displays in the conduct of duties of the highest importance and his distinguished services have been recognised by the honour which he has received from His Majesty the King.

With Mr. Greenway I have also had many years of business relations on behalf of the Admiralty and have been associated with him in the solution of many difficult petroleum problems. I share the admiration which I know you all feel for him as a man and for his wide knowledge of petroleum matters and his great business capacity. The vigour which he has displayed in carrying out oil developments has been of signal benefit to the allied cause. I have marvelled as you have also done at the reserve of energy which has enabled him to give time to the affairs of the Institution with business cares of so engrossing a character upon his shoulders. I am, of course, speaking of Mr. Greenway's personal merits. Of the work of his Company and that of other Companies I shall have a word or two to say later on in this address. I must not fail to say how much I appreciate an extension of acquaintance with your Hon. Secretary, Mr. A. W. Eastlake, whom I congratulate on his own good work during the war, and upon that of his son, Lieut. A. Lloyd Eastlake, R.E., who not only did valuable research work on flame-projectors and smoke screens, but was one of the gallant band who sailed in the "Vindictive" against Zeebrugge, in the same fine spirit of adventure that animated Jason in the Argo, Francis Drake on the Spanish Main, or Admiral Cochrane on the coasts of Chili and Peru.

In speaking of one of the many supply problems of the war—and I shall deal with my subject to-day in not too severely technical a

manner—I feel profoundly that whatever share anyone of us may have had in the work of supporting the allied forces by the providing of essential material, our duty has been on a lower plane, compared with that of the sailors and soldiers and the Air Force. Their personal risks and sacrifices transcend those of the civilian. Nevertheless, when one thinks of the casualties that have befallen many civilians, and of the harassing and anxious times they have passed through, when one remembers valued friends who have gone under in the struggle, or when one looks at the drawn and hardened faces of many of those who have survived, one realises that the strain of the war has been not so unevenly distributed after all, and that the civilian may claim that in his place and calling he, too, has proved himself not altogether unworthy of his country or of the great cause for which his country has been contending. In the interesting speech to which the Petroleum Technologists listened from Admiral Sir Hugh Tothill, 4th Sea Lord of the Admiralty, at the 1st annual dinner of the Institution on the 25th March, mention was made of two officers who held in succession the important and onerous appointment of Director of Naval Stores in the Admiralty, viz., Sir John Forsey and Mr. M. M. Waller, both of whom died from the effects of the overwhelming strain of war duties, largely connected with the supply of coal and oil to the Navy.

There is another instance of the death of a zealous and capable official of the same department—Mr. George Day, which also deserves to be put on record. Mr. Day's duties were also in connection with fuel, and during the Boer War he rendered good service to the Admiralty on coaling duties at Capetown. During the whole of the late war he undertook voluntarily an exceptional share of the trying night work which of course devolved necessarily upon large numbers of the staffs of the Admiralty and other Departments.

Other speakers more influential and other tongues more eloquent than mine have spoken of the debt which civilisation owes to the fighting forces of the Allies, and to bodies of men not actually enrolled in the Navy or Military forces, such as the officers, engineers and seamen of the Mercantile Marine, who throughout the war ran the same risks as the fighting services, and passed through the waters literally carrying their lives in their hands.

A word may here be said of the special risks of men in the tank steamers that came overseas with our supplies of petroleum oil. You may have read of two cases reported in the newspapers, one in which a tanker was torpedoed, and the other in which the vessel

was in collision. In each case the sea was covered with burning naphtha, and the crew had to pull for their lives to escape the pursuing flames.

Another reflection also arises, and it is this—how rapidly events and actions which at the time seemed and actually were of high importance fade into ancient history. So urgent and insistent in these times are the problems of the present and the future, that it seems almost unprofitable to spend time in recalling the past, unless it can serve in some fashion to throw light on the problems of the present.

Coming now directly to my subject—I was reading a short time ago that interesting address of Sir Boverton Redwood's on the "Romance of Petroleum." In his concluding paragraph he points out how much more entertaining his paper might have been but for the necessary limitations of official secrecy. Those limitations still exist, of course; but with the conclusion of the war there is a larger measure of freedom, and it is now permissible to take stock to some extent in public of our experience, and consider its relation to present-day problems. Many of you may remember that Lord Curzon in a speech which he made at Lancaster House in November last, was able to state publicly the nature of some of the petroleum problems that confronted the Allies in the months of June and July, 1917. At that date a very serious attack had been made by the Germans upon the tank steamers that brought oil to Europe for naval, military and civilian purposes. The reserves of petroleum products for those purposes were below the standard that was desirable for security. Rigid economy was exercised in respect of the use of petrol for all non-essential services. At the same time, in spite of all the economy that could be exercised, the requirements of heavy fuel for the Navy and of petrol for motor transports and aviation were constantly on the increase. The organization of distribution for civilian purposes through what was known as the Pool Board, under Sir Walter Egerton, effected a considerable economy; and the Petrol Department, first under Mr. Berry and afterwards under Sir Evan Jones, kept a firm control over the use of that material for all civilian purposes, and stamped ruthlessly, but justly, upon all consumption for luxury and even convenience. I must not omit to mention here the credit that is due to Mr. George Booth and Mr. Houghton Fry of the Ministry of Munitions, and the late Mr. Waller of the Admiralty, for their share in the earlier development of that organization, nor to the valuable assistance of Sir Hubert Llewellyn Smith and Sir William Marwood of the Board of Trade.

Anyone who has been long associated with questions of fuel supply is inclined at times to make comparison with the easier problems with which his predecessors may have been occupied. It has been my lot to be connected with the fuel supply of the Navy now for upwards of thirty years. That period has been one of continual growth in the quantities required. The most important development in the descriptions of fuel adopted for naval use in the last 18 or 20 years has been the far-reaching change of part substitution of oil fuel for coal. For hundreds of years, from the earliest beginning of the British Navy until considerably after the days of Nelson, the principal requirements of the Navy so far as propulsion of ships was concerned were of course cordage and sail cloth; and fleets could keep the seas for many months without need of returning to port for fresh supplies. The introduction of steam brought fuel problems into consideration for the first time. The fuel question whether it may relate to coal or oil must always have its elements of anxiety. During the great coal strike of 1898 a much-harassed Admiralty official relieved his feelings by some verses in which he sang the praise of those happy times:

> "When Britain's tars fought all her wars,
> Without a coaling station."

If coal, an indigenous product of the United Kingdom, presents its doubts and difficulties, what is to be said of petroleum oil, which only to a very limited extent is obtainable in this country? I recall the anxious consideration which the Board of Admiralty and the Royal Commission under Lord Fisher gave to the question of the possibility of obtaining and transporting adequate supplies of heavy oil fuel, if a certain proportion of His Majesty's ships were to be oil burners.

Some time before the war, it fell to my lot to go into statistics and estimates of oil production and consumption all over the world, not merely at the moment but for a specified term of years ahead. This was to assist the Admiralty in regard to possible further substitution of oil for coal.

After this lapse of time, official reticence may be sufficiently relaxed to permit me to say that I was able to make a satisfactory report of the possibilities of oil supply subject to certain safeguarding conditions, and it is satisfactory to be able to say to-day that the conclusions at which the Admiralty then arrived have been fully justified during the war in the efficiency of ships and the supplies of fuel that were actually available. Sir Tennyson D'Eyncourt, Director of Naval Construction, was able on 9th April to tell the Institution of Naval Architects something of the part

that oil played in the wonderful development of the British Navy during the war.

The estimates of possible petroleum requirements which were formed before the war were far exceeded by the actual needs of the stupendous struggle from which we have just emerged. The advantages of oil in battleships, swift cruisers, destroyers and patrol boats were however so great that, notwithstanding all difficulties of overseas transport, oil fuel took its place in the front rank of essential war supplies for naval purposes; and during the war a demand far in excess of possible estimates had also to be satisfied for petrol or gasoline for military motor transport and for aviation purposes.

It was not only a question of increased quantities that had to be dealt with, but the fact that those increases were not in uniform proportions of the various products. Consequently difficulties of refinery adjustments as well as of production and transportation had to be met. The main problems may be specified under three heads:—

(1) Whether the world could produce the aggregate supplies that were required for the service of the war.

(2) Whether the processes of refining could be so adjusted that the increased quantities of heavy fuel could be obtained, as well as those of petrol or gasoline, particularly of the high grade required for aviation purposes.

(3) Whether sufficient tank steamers and tank cars could be provided to transport and distribute by sea and land the necessary quantities of each product.

Although the foresight and enterprise of great commercial companies and of Government Departments had done much before the war to make further development possible, there were many contingencies that could not be foreseen or provided for beforehand. Probably very few people indeed anticipated that a time would ever come when through shortage of labour and means of transport a serious deficiency of coal would occur in the United Kingdom at the same time that the demand for oil products became so acute.

The Admiralty may fairly lay claim to a great deal of foresight in respect to fuel problems, but I doubt whether many of us in that Department ever visualized a set of circumstances in which the Admiralty would be glad to obtain supplies of oil, not only because of its intrinsic merits, but also because coal would be at the same time in enormously increased demand for naval, military, munitions, industrial and domestic purposes, and that the coal supply would be diminished by the conversion of many thousands of miners into soldiers.

Another aspect of the coal and oil problem was the requirement of certain products for use as high explosives. The use of picric acid, obtained from coal, was well established before the war, but in this country the use of toluol, also obtainable from coal, was in the early days of development. The use of toluol benzine extracted from Borneo oil, which at the suggestion of Sir Marcus Samuel was brought to this country, and plant erected for the separation of the toluol and for its nitration, was therefore a valuable addition to our supply of high explosives. Experiments were made later on, both here and in America, to obtain similar results with petroleum from other sources.

It is known of course to all who are interested in petroleum matters, that at all times since petroleum oil became one of the world's important supplies there have been great fluctuations, not only as between the supply of oil and the market demand, but also in respect of the adequacy and cost of the means of transportation by sea or land, i.e. by tank steamers and by tank waggon or pipe-line. It occasionally happens that new oilfields of great productivity are discovered, and great gushing wells pour forth their contents more rapidly than man can provide storage for, or facilities for refining and transport. Consequently, oil may be at one time very cheap, and at another very dear, and the freight or carriage of oil also fluctuates widely. Oil tankers may be found at one time in large numbers at their moorings, and at others every boat is in active employment.

The carriage of oil across the Atlantic has varied in the last ten years from, say, eight shillings a ton to very nearly as many pounds per ton. When oil is very plentiful the sellers seek for market wherever they may be found at home or abroad, and railways and factories and steamships may find it economical to substitute oil for coal. The building of oil refineries, oil storage, tankers and pipe-lines will be stimulated till supply and demand and means of distribution are again in approximate equilibrium. The pioneers who are always going forth to find new supplies of oil must also have the necessary inducement to continue their labours. Scientific research, pioneer enterprise and technical manufacturing talent, and the skill of the merchant in finding and supplying markets, have greater scope for their energies in co-operation and in competition in the oil trade than in almost any other.

And there are few commodities except food and clothing of which the world's need is greater. I do not think you will regard it as any exaggeration on my part, when I tell you that in all my discussions with my American friends as to procuring larger supplies

of oil or more tankers, I referred invariably to oil and ships as two of the great pillars which supported the world's civilization and ordered freedom. Speakers and placards here and in America have reminded us that more men were wanted to win the war, or that food or money or aeroplanes could achieve that result. We have been told that this was an engineer's war or a chemist's war, or a manufacturer's war, or a business man's war and, last but not least, that the war has been won by women as much as by men. All these things are true, but it may yet be said in a very special sense that without sailors and an abundance of ships and petroleum oil on the side of the Allies, the chances of success of the Central Powers whose forces were mainly on land would have been infinitely greater. The dependence of the enemy on oil was also very great, for without it the machinery of their industrial and munitions production and transport would have come to a dead stop.

Now a word for the great Oil Companies. Some years ago it happened that America had a large new production of oil about the time the British Admiralty became consumers on an important scale. This led to our getting into closer touch with great companies like the Standard Oil, Gulf, Texas and others. We had business relations with all of them, which I think were honourable and creditable to all concerned. We have also had excellent relations with and the greatest help from the British Companies, such as the Burmah Oil Company under Mr. Cargill, Lord Cowdray's Mexican Eagle and the Shell Group under Mr. Deterding, Sir Marcus Samuel and Mr. Cohen, not forgetting the Anglo-Persian Oil Company under Mr. Greenway.

In different ways and in different parts of the world each of these great Companies had shown immense enterprise in developing fresh supplies of oil, in erecting refineries, in building pipe lines and tank steamers and opening up new markets. When war came, all these things were a valuable asset to the Allied cause. The pioneer work of Lord Cowdray in building a number of large tank steamers proved of high value. As I have already said, practical help came from the Shell Group in respect of high explosive supply, also in the distribution of motor transport spirit to the Army and in the fitting of the double bottoms of cargo ships for oil transport to supplement tank steamers.

The Anglo-Persian developments to which Admiral Sir Edmond Slade's commission materially contributed, gave us much of our Mediterranean supply and most valuable assistance to the military forces on the Tigris and in Mesopotamia. I must not omit a reference to useful supplies by the Trinidad Companies, and, last

but not least, to what was done at home by the Scottish Shale Oil Companies, whose services had always been highly appreciated by the Admiralty in peace time, but whose co-operation in war time became of still greater importance. The mere mention of the names of three Scotsmen—Sir George Beilby, Mr. Cargill and Mr. Fraser—whose names we associate with Scottish oil enterprise in either its scientific or its commercial aspect in Scotland and Burmah and elsewhere, will serve to dispose of the suggestion that Britishers are temperamentally handicapped in matters pertaining to oil.

In the examination and measurement of shipments of petroleum products to this country, and in other ways, services of high national value have been rendered throughout the war by a member of the Council of your Institution, Mr. Robert Redwood, in the face of exceptional difficulties arising from the depletion of his staff, most of whom were serving under the colours.

From the latter part of 1916 and onwards the Ministry of Munitions and the Admiralty under the able guidance and advice of Sir Boverton Redwood, Sir John Cadman, Mr. Cunningham Craig and later of Sir Arthur Churchman, Sir Keith Price, Mr. Winmill, Commander Shaw and many others had given special attention to the home production of oil from shale and cannel coal. At a very important meeting held at the Ministry of Munitions, it was urged that even if we got ahead temporarily of scientific advice, we must go forward during the war with home production. Sir John Cadman and Mr. Fraser and other experts took in hand further developments in Scotland. In the then state of knowledge and development of processes of high-temperature and low-temperature distillations, there was necessarily much room for doubt and diverse opinions both as to the best systems of distillation and as to the resources of cannel; and, further, even if those resources were as large as was believed to be the case, there were the practical questions, whether labour and transport could be made available for mining and transport as well as for provision of retorting and distilling plant. The line of immediate progress was found to be the use of retorting facilities at some of the existing gas works of the country. Much useful work was done and knowledge gained, a distinct step forward was taken; and although in time of peace with cheaper transport of imported fuel, the home production will have special difficulties of cost and disposal of products to contend with, it need not be doubted that home production of oil from cannel and other coal will sooner or later be one of the sources of supply that the market will need. Your Institution assisted in research work in this

direction which will no doubt prove a useful contribution and supplement to the efforts of others.

At a later date the drilling for oil in this country was taken up under Government auspices, with Lord Cowdray's valuable assistance. The results of this are still awaited.

I must not omit a reference to the difficult situation in obtaining sufficient lubricating oil—owing to shortage of shipping. In this matter Mr. Houghton Fry and the oil importers, with the assistance of the Ministry of Shipping, did much good organizing work which saved us from serious danger.

The Oil Committee under the Right Honourable E. G. Pretyman, Civil Lord of the Admiralty, examined our oil problems, and gave timely guidance. At a later date that organization was extended and placed by the Cabinet under the direction of Mr. Walter Long, Secretary of State for the Colonies, who co-ordinated the petroleum needs of Great Britain and the Allies, through the Petroleum Executive under Sir John Cadman, aided by Mr. G. H. Ashdown, C.B.E., Director of Naval Stores, Mr. J. C. Clarke, O.B.E., of the Admiralty Contract Department, Mr. B. A. Kemball Cook, C.B.E., of the Ministry of Shipping, and our French and Italian allies.

In June, 1917, I returned from munitions work in India, and in July of that year, Mr. Walter Long and Admiral Tothill, 4th Sea Lord of the Admiralty, told me that it was my duty to proceed to America to assist the British War Mission under Lord Northcliffe in arrangements with the American Government and the American oil trade in obtaining supplies of oil and assistance of additional tank steamers. The American petroleum production, as you are aware, is about 70 per cent. of the world's total, and her tanker tonnage was nearly one half of the total tanker tonnage of the world. Her shipbuilding capacity was also being rapidly developed; consequently American co-operation and goodwill in oil supply and transport, as in so many other directions, were of vital importance.

I went to America in July, 1917, and returned to England in September, 1918. For the first three months I had the valuable aid of Mr. Waley Cohen, of the Shell Company, besides the great assistance of Sir Thomas Royden, Bart., and many other members of the British War Mission, including Sir Andrew Caird, K.B.E., Sir Ashley Sparkes, K.B.E., Mr. Boyd, C.B.E., Mr. Hewan, O.B.E., and, not forgetting in later stages, Sir Henry Babington Smith, K.C.B. Mr. Hewan did yeoman service at the head of the Oil Executive Branch of the British Ministry of Shipping in New York. Mr. Taphouse, lent by the Shell Company, did technical work of a

highly important character in respect of the use for oil carriage of the "double bottoms" of merchant ships, and Mr. Zulver, of the same Company, assisted similarly in Europe. I received valuable help in the Secretarial work of my New York office from my wife and my daughter (Miss Dora Black, M.B.E.), also from two lady members of the British Ministry of Shipping staff, Miss O. C. Smith and Miss G. A. Smith, M.B.E. It was to me a high privilege to be permitted again to serve the British Navy in this particular capacity. The time was not only critical in oil supplies and the fortunes of the war, but in America the general situation of the attitude of the people towards the war was intensely interesting. The minds of American people had been made up to organize the man power and the financial, material and industrial resources of the country to strike a great and effective blow at the enemy. The great question was could men, ships and supplies be got ready in time. The part that English officials had to play was to give to our American friends the full benefit of the experience we had gained in three years of war, so that as far as possible America might begin at the point we had reached, and not have to buy her experience as dearly as we had bought ours. In this way the war could be shortened and valuable lives and treasure saved.

I need not take you in detail through the various preliminary and difficult stages by which in the matter of petroleum supplies, the official organizations of America and the Allies were brought into working order and co-operation with one another and with the American trade. It will be simpler to state briefly what the organization was when it got into its stride. At Washington, but with a branch at New York, was located the oil branch of the U.S. Fuel Administration. The head of the Administration was Dr. Garfield, but the oil branch was in special charge of Mr. Mark Requa, an able mining engineer who in circumstances of great difficulty rendered conspicuous service to his country and the allied cause. The requirements of Britain (including Pool Board supplies), France and Italy were cabled to the British War Mission by the Petroleum Executive under Sir John Cadman, and were put into the hands of Mr. Requa, who arranged with the Oil Trade Organization, known as the National Petroleum War Service Committee under Mr. A. C. Bedford for the allocation of the orders to the refineries. A schedule of prices was agreed upon by the U.S. Government and the oil trade, and the various Missions arranged for loading tankers at specified ports. All these arrangements, when the first preliminary difficulties were got over, worked exceedingly well.

The American Government Shipping Board under Mr. Hurley had in hand the organizing of shipbuilding, and the Ship Allocation Committee under that Board arranged for the distribution of American merchant shipping for all services. Mr. Franklin was the President of that Committee, Sir Connop Guthrie was the British representative, and Mr. Walker was the able and hard-working secretary. Now all this sounds very simple and easy and as if everything went like clockwork and as merrily as a marriage bell. It is true that essential requirements were met, but the difficulties to be overcome in America were as great as those that had to be contended with in Europe, and the success achieved was due to hard, unremitting practical work on the part of all concerned, and the exercise of business ability of a high order.

It is not always realised in this country that the whole oil trade of America is not run by one great Corporation, but there are a large number of competing interests between whom considerable rivalry existed. No small part of the many problems which confronted Mr. A. C. Bedford, President of the Standard Oil Company of New Jersey, was the securing of co-operation among rival trade interests. He succeeded in this as in other matters by a statesmanlike and masterly handling of the whole situation. The Petroleum War Service Committee in its final shape was fairly representative of all the oil interests of America, and whilst the oil trade retained the control of its own business it co-operated most effectively with the American Government in meeting all the requirements laid down by the Fuel Administration.

I accompanied Mr. Bedford and other members of his Committee in the autumn of 1917 to Chicago, Kansas and Oklahoma. We had the pleasure of meeting Dr. Burton at Chicago, and seeing something of the "cracking process" associated with his name. At Kansas and Oklahoma representative meetings of oil producers were addressed by Mr. Bedford and myself and many others and, thanks to the patriotic attitude of Mr. Bedford and the oil producers in general, co-operation was secured on all sides. Visits were paid to the oil fields of Eldorado and the famous Cushing Pool. Incidentally I may mention that I saw a 20,000 barrel "gusher" in Kansas, but a few days later we heard that water had broken in. In the mid Continent I met a number of practical drillers and also the superintendents of pipe-laying engineers, and found the greatest interest in war production prevailing amongst them. I remember one of them telling me that he was waiting for a talented novelist with eyes to see, to come that way and get all the colour and material for a new romance.

My friend Mr. Jim O'Neill related many most interesting anecdotes and experiences, which combined with the exhilarating qualities of the climate and the freshness and simplicity of the prairie life, made me exclaim: "Almost thou persuadest me to be a pipe-layer." There was a warmth of heart amongst the men that I met on the oil fields in the mid Continent and afterwards in Texas and Louisiana that made a strong appeal to me.

It was due to what I saw out West that I was able to furnish the Admiralty with information to assist in obtaining men and materials from America to enable them to proceed with the projected oil pipe line from the Clyde to the Firth of Forth, to save tonnage then occupied in the voyage round the North of Scotland. The honour of the initiation of this scheme seems to lie between the Admiralty and Mr. J. Smith of Lord Cowdray's staff. We are indebted to Mr. Forrest Towl, an eminent American pipe-line engineer and to his son Lieut. Towl, also to Commander Barstow, of the U.S. Navy, for most valuable work in this connection. To-day Scotland is divided into two parts, N.O.P. and S.O.P., north of the pipe and south of the pipe, and a belt of American oil is the dividing medium, but as between Great Britain and America this streak of oil sentimentally considered may be regarded as a bond of union connecting us with our kinsmen on the other side of the Atlantic who supplied the pipe material and the oil, and it certainly forms no barrier between Scotsmen and Englishmen.

Although my main purpose is to tell you of oil problems on both sides of the Atlantic and of the steps taken to overcome them, and not merely to entertain you with a descriptive account of travel in America, I think you will regard it as excusable if I mention in bald outline at least some of the places, oil fields, refineries, etc., which I visited and interesting things which I saw. My duties took me frequently between New York and Washington to confer with the U.S. Government officials and the oil trade. I visited Canada, and had the pleasure of meeting the Governor-General and the Prime Minister at Ottawa, and also of going in detail into all the arrangements at Montreal under Sir Arthur Harris for storage and shipment of fuel oil to Europe. We were fortunately able to send oil to some extent to Canada direct from U.S.A. by tank car to economize tank steamers and relieve the congestion on the pipe lines. Our Canadian friends helped us most loyally and energetically.

In Texas and Louisiana as well as in Oklahoma I was able to see oil drilling and pumping on all the great and well-known fields, and the refining carried out at such important refineries as those

of the Gulf and Texas Companies at Port Arthur and of the Standard Oil Co. at Baton Rouge. The loading facilities at those ports and at Beaumont and Galveston were also visited. The appearance of an oil field with its forest of derricks, usually made of wood but occasionally of steel, under which drilling or pumping is carried out, need not be described, as this is all familiar to you either from actual experience or from your study of the standard works on these subjects. You have recently had a paper by Mr. Maurice Ockenden and Mr. Ashley Carter giving a technical description of plant used in the percussion system of drilling for oil, and the uses of the rotary drill are also well known to you.

To see the string of drilling tools come up from the depths of the well, to watch the flow of the oil, to note the efforts to collect it in all kinds of vats and temporary tanks till pipes can be laid to the tank farms, to talk with drillers and pipe layers—all these things give a real live interest to oil problems which one can never acquire in quite the same way in a laboratory or the lecture-room.

As you are aware, oil is found in regions that differ very greatly n their external physical appearance. The Cushing Pool of Oklahoma for example is in a forest district, whilst many wells of the Goose Creek field are actually sunk beneath the waters of the creek, and the same feature characterizes some of the Californian wells. An important yield of oil is obtained from the numerous small wells situated often in land that is cultivated for corn or maize on the surface. In the midst of a great cultivated area will be found a small corrugated iron shed containing the machinery which operates a number of small jack pumps to which at considerable distance and at various angles run the rods which operate the pumps. These rods are not readily perceptible at a distance, consequently the up and down and to and fro movement of the pump lever or handle seems to be automatic or worked by an unseen magician. Wells of this kind yield their useful contribution of three or four barrels or more apiece per day.

The pumping stations and storage and measuring tanks on the great trunk pipe lines well repay a visit. The system of checking quantities into and out of the tanks and of telephoning from station to station what quantity should come along are of a very complete and practical character. The oil moves as a rule through the pipe in ordinary gradients at about the same pace as a man would walk, and pumping stations are frequently as much as thirty miles apart.

There is a feature of interest also to be noted in the solitary derricks which are usually to be seen a mile or two ahead or behind or to the right or to the left of the prolific section of the field. These

mark the scene of trial borings to extend the field, and are often the "dry holes" of the "wild catter" or explorer, who is confronted by many disappointments, but often enough meets with sufficient reward to encourage him to continue his labours and add materially to the aggregate of new production. A feature of oil drilling is the code of honour, seldom departed from, which prescribes the distances between wells situated on property belonging to different owners. Where four leases happen to meet, a well is to be found in each corner at the prescribed distance. The romances of oil fortunes have often been described—one sees to-day on the plans of an oil field many quaint names, and on enquiry these may prove to be the names of Indian men and women and even children who have come into large possessions through oil being struck under their farm lands.

The towns that grow up around a prolific oil field rapidly become important business centres with comfortable homes and clubs and always with good churches and schools. Even when the houses, offices and shops of an oil mining town are still in the wooden board and sawdust stage, the school will be there on one of the most commanding sites—a handsome stone or brick structure—well equipped with an excellent staff of teachers. My visit included a hasty glimpse at one or two American military camps and aviation stations. I have entered upon this digression in order that I may not appear in the light of either an unobservant visitor to scenes of such great interest, or unsympathetic and unmindful of the great kindness and courtesy with which my American friends uniformly treated me, or the fine zeal with which industrial America threw itself into the production of war material.

It was highly gratifying to me when I was in New York and Houston of Texas, Tulsa of Oklahoma, and other fuel oil centres to find my department, the British Admiralty, was most gratefully remembered by virtue of its large and always equitable dealings with the oil trade of America, and Americans everywhere greeted any reference to the British Navy with kindness and enthusiasm. Probably nowhere in the world did the Zeebrugge exploit attract more attention and evoke so much admiration as in America.

On one occasion I had to follow ex-President Taft in saying a few words to a large gathering at Newark, New Jersey. On that occasion I had the great pleasure of hearing Mr. Taft's cordial appreciation of the great sacrifices which Great Britain had made in the war. This sentiment was indeed general throughout America, and especially of course amongst American citizens of direct British descent.

At the refineries the cracking process and methods of taking out gasoline from casing-head gas are the more modern features. It is interesting also to note the subsidiary industries that are often connected with the refineries, such as the plant for making kerosene and petrol tins, or wooden or steel barrels, or for transforming the wax into candles, or again for the use of oil for the proofing of felt as a roofing material.

Few people will realize outside the ranks of those who had to handle the situation, what difficulties had to be met through the enormous demand for tin plate for the packing of oil and of food products for armies and navies. There was a good supply of tin in the world, but thin steel sheets for tinning were more difficult to obtain because the labour and rolling plant were required for other urgent war services. I had seen in India how the kerosene tin which is usually sold for a very small sum, and utilised by the natives to make roofs for their houses and many other purposes, had to be collected and bought in at quite a high price to be re-shaped and used three or four times over for distribution of oil. The Ministry of Munitions in London set itself to work in active and practical fashion to economize tin plate and find substitutes in every possible direction. Some of those substitutes you have seen in the grocers' shops in the shape of cardboard containers for products usually packed in tins or bottles. In the United States, the Government gave special attention to distribution of tin plate according to urgency of needs. The requirements of tin for containers of food sent from U.S.A. to Europe were of course on a very large scale. The problem of supply of steel tubes for pipe lines and oil well casing for American and British oil Companies was also an extremely difficult one, owing to the heavy demand for steel for war purposes. The available supplies of oil well equipment had to be strictly apportioned to the needs that were most pressing.

I must now proceed to give you some idea of what America's other petroleum problems were, I mean other than those matters of organization, to which I have already referred. I had not been in America very long before I became convinced after close consultation with American oil experts that there was no doubt as to America's ability to supply all the petroleum oil of the various descriptions which the Allies might require from that country, provided transport could be found. These requirements were very large, being in the neighbourhood of half a million tons per month of all products. To meet these quantities America had to draw very heavily on her accumulated stocks of crude oil, and at the

request of the U.S. Government the large Oil Companies in very helpful fashion placed a substantial proportion of their stocks at the disposal of the smaller refineries.

Mr. Requa and Mr. Bedford took in hand also the difficult question of stabilising the prices of crude oil, and effected an arrangement as to the maximum prices which might be paid as premiums above the posted prices.

At the time when the demand for oil became acute in America, there was in that country as in the United Kingdom a very restricted coal supply, due to shortage of labour and difficulties of transport, accentuated in America by an exceptionally severe winter. We had "fuelless" days in New York with a temperature sometimes of 15 degrees below zero. Railway waggons were buried in snow-drifts and the bunkering of ships was suspended on one occasion for some 10 or 12 days. The demand for fuel both coal and oil for munitions and steel production was also very great. The U.S. Government instituted a priority scheme for dealing with fuel requirements according to their relative urgency.

In recent years America has supplemented her own supplies of oil by a considerable importation from Mexico, which is blended to a large extent with American oil. The United States Navy fuel oil specification admits of a sulphur percentage which enables the refineries to include a proportion of Mexican oil. At the same time the blast furnaces and metallurgical works were asking for oil of low sulphur content. The American Government pressed upon the Allies the necessity of taking at least some proportion of their heavy fuel oil requirements to the American naval specification, and we were able to come to an arrangement in that matter. The whole subject of specifications was exhaustively discussed between the British War Mission and the American Authorities. American experts, Mr. Narramore and Mr. Purdew visited Europe to confer on that subject, whilst experts from Europe, Engineer-Commander Hyne, Mr. Fraser, Mr. Conacher and Captain Gooday visited America. The specification question presented special difficulties in regard to aviation spirit. Refinery experts will appreciate that there is a great reduction in output on a given refining capacity according to the final evaporation or end point that is insisted upon. The refineries were accustomed to produce ordinary motor spirit to an end point of about 430° Fahrenheit. The British aviation spirit had an end point of 302° Fahrenheit, which was found to be within reasonable refining capacity.

America had not previously supplied any large quantities of aviation spirit, and it was the duty of the Allied representatives,

whilst anxious to meet the refiners difficulties, to keep the user's point of view continually to the front. The man who risks his life in the air must know what his engine will do with certain fuel, and he must be supplied with the quality that will meet his requirements under trying conditions of changes of temperature.

After some initial difficulties both of refining and in transport, America developed a large production of aviation spirit. There came a demand later from some of the Air Forces in Europe for a certain proportion of aviation spirit of an end point of 257° Fahrenheit. This was a very serious matter, as it meant a great reduction of refinery output. Fortunately the quantities of that grade that were asked for were relatively small, otherwise a situation of considerable difficulty would have had to be met. It will be readily understood that not all the refineries in America, as elsewhere, possessed the same facilities or expert knowledge to put out the highest grades, but it is impossible not to feel great admiration for the technical skill and adaptability to new requirements that was displayed almost universally.

The same tribute is due to the general business arrangements of the Petroleum War Service Committee. I cannot mention all the names, but I have here a photograph of the principal members with their names at the back.

I must not, however, omit reference to Mr. W. C. Teagle and Mr. James Moffett. Our American friends required of us that we should prove our case as to the seriousness of our needs and the economy of our methods. They sent to Europe Commander Foley of the U.S. Navy and Mr. L. I. Thomas to keep in close touch with the British, French and Italian representatives. Mr. Bainbridge Colby, of the U.S. Shipping Board, also visited Europe, and on his return delivered impressive speeches as to the extreme urgency of the situation, and exerted great influence in speeding up tanker construction, and in various measures calculated to place an increased amount of tonnage on the Atlantic route.

This brings me now to what was always the real crux of the situation, viz. insufficiency of tank steamers, due not to any want of foresight, but to unavoidable losses and damage through submarine action and marine risks and the loss of carrying power necessitated by the convoy system, as well as by the fact that exigencies of war did not permit of the boats being discharged and turned round with the promptitude that is usual in commercial business in normal times.

The transportation to Europe of the quantities required from the United States alone, excluding Mexico, Trinidad, Borneo and

Persia, necessitated the constant employment of over 1,000,000 tons carrying capacity of tank steamers. Tonnage was also required for distribution to the fleets, etc., for coastal traffic in America and Europe and the East and for keeping the markets of the world going on a severely rationed basis. The coolie of India and China had to submit like the English cottager to smaller supplies and higher prices of kerosene for lighting and cooking.

It was my duty in America to keep before my American friends the necessity for more tank steamers. America created shipbuilding yards and trained shipyard labour for the production of merchant tonnage generally, on the top-notch of urgency under the direction of Mr. Hurley and Mr. Charles Schwab and other members of the U.S. Shipping Board. Great shipyards grew up or were enlarged on the Pacific and Atlantic coasts. Hog Island, near Philadelphia, was created in a few months on the site of a marsh. There were 50 building slips at that yard alone. The parts of ships were fabricated in various factories and engineering shops all over the United States and were assembled and put together at the shipyards. It would be foreign to my subject to discuss relative costs and efficiency of ship construction work, or what may be the effect on the shipbuilding or sea-carrying trade of Great Britain or other nations, of this great development in America; but it stands as a great achievement of emergency organization, worthy of comparison with the magnificent work which the British shipbuilders and repairers were doing at the same time under circumstances of exceptional stress and difficulty.

America in her shipbuilding had special difficulties of training of men to contend with and her weather conditions in 1917 and 1918 were none of the best. I visited shipyards at Philadelphia and Chester on tne Delaware and on the Fore river near Boston in the severe winter weather at the beginning of 1918. I marvelled that shipbuilding work out of doors could be pressed on with whilst snow and ice lay thick on all the exposed parts. It was almost equally surprising on a later visit to Philadelphia in August, 1918, with a shade temperature of about 105° to find that records of riveting were being established. I have here a portrait taken from the *Philadelphia Ledger* of one of the riveters who made a record in that month. The portrait is called the "Spirit of American Labour." It needs no great effort of the imagination to regard this giant figure as typical of many thousands of workers in all the allied countries.

It will be readily understood that only a part of the shipbuilding and repairing capacity in either the United Kingdom or America

could be appropriated to tank steamer construction and repairs. Such work was necessarily liable to be set back by an even more urgent demand for other classes of tonnage. Consequently the aggregate of disabled tonnage waiting repair reached at times a very large figure, and progress with new ships did not always come up to anticipations.

It may be mentioned here that many of the merchant ships built in America are fitted to burn oil, and this will be a factor in the near future in respect of the world's consumption of heavy fuel oil. To put as much oil tonnage in the overseas trade as possible, it was necessary for America to restrict coastwise carriage of oil from Mexico to ports in the U.S.A. and on various other trade routes. Great Britain had adopted a similar policy.

In this connection some particulars may be given of one of the special adjustment problems that arose in our efforts to utilise tanker tonnage in the most economical way. This particular problem raised also some technical difficulties in regard to refinery operations, but in the main it was a problem of business organization of supply and transportation to enable certain markets to be supplied with petroleum products from a nearer source of supply than was normally the case, and so accomplish an economy of tanker tonnage that would place more at disposal for war requirements.

The doctrine of "supply from the nearest source" was readily accepted by all concerned, but its application involved the discussion of problems of a very difficult nature. I need not enter into details, but briefly the situation was this. In normal times America, by virtue of her large producing and refining facilities, is able to supply a considerable proportion of the kerosene used in such distant markets as those of India and China, the remainder being met from Eastern oilfields and refineries. The question was whether a larger quantity of the desired quality or a near approximation could be provided in the East. This meant changes in refining and in proportion of products, and consequently much alteration in the relative quantities of various products marketed by different agencies, and an adjustment of the voyages of American and British tank steamers. These complex questions were discussed with great thoroughness on both sides of the Atlantic, and a rerouting scheme, as it was called, was finally adopted. The adoption of carriage of oil in double bottoms of ships, to which I have already referred, and with which the name of Mr. Kemball Cook is honourably associated, did more than any other single effort to relieve the situation. Lord Curzon mentioned in November last that over 1,000,000 tons of oil were conveyed overseas by that means.

Admiral Tothill also recently gave us interesting information on that subject. By this and other means the building up of our reserves was satisfactorily achieved.

The question of conservation of supplies or restriction of use in America was partly dealt with by means of the U.S. Government priority scheme already alluded to. Further steps had to be taken much as in this country to restrict the use of petrol or gasoline for pleasure purposes.

In the early days of my visit to New York I found America keenly alive to the necessity of conservation of essential supplies by restriction of luxurious consumption. This restriction was brought to bear upon coal consumption at a very early stage, and later upon certain articles of food. The necessity of economy in the case of fuel oil was also being pressed both for the sake of diverting transport from commercial to war services, and to reduce the heavy drain upon stocks of crude oil. The necessity of conservation of gasoline or petrol was, however, not so apparent at that stage. It was argued by the Petroleum War Service Committee and other authorities that as the lighter fractions had to be taken off in order to obtain the fuel oil, kerosene and lubricating oils, there was no need to restrict the use of gasoline; and in fact it was regarded as a fortunate circumstance that there was so good a domestic market for that product, seeing that the sale of gasoline at a good price necessarily enabled the other descriptions that were required for war service to be put at the disposal of the Allies more economically than would otherwise have been the case. It was, moreover, urged that storage was not available, and of course the destruction of a valuable product was agreed on all hands to be out of the question. I did not dispute that there was much force in these arguments which were widely and authoritatively promulgated in the American press.

I strongly contended, however, in all my many conferences with my American friends, that

(1) It was economically unsound to consume for purposes of luxury a power-producing product of such importance as gasoline, and that sooner or later such consumption would have to be stopped, especially in view of the growing needs both of high grade spirit for aviation and of navy fuel oil.

(2) I recognized that it was not practicable by the wave of a magician's wand suddenly to transform this wasted gasoline into a profitable use for power-production in other types of machinery; nevertheless there was waste going on, and it seemed to me that here was a problem to which chemists, engineers, petroleum technologists

and business men might apply their brains to find some more profitable use.

(3) I further represented that at any rate the cracking process was in many cases actually producing gasoline at the expense of heavier oil that could be used as a fuel which was in great demand. This was not disputed, and it was agreed by the war service committee that if and when means of transport for the additional fuel oil could be found, the continuance of cracking to the detriment of production of heavier fuel oil would not be justifiable.

Whilst this question was the subject of much official discussion I had the pleasure of attending a dinner of the Twilight Club, of which I had been made an honorary governor—an honour by the way I may mention I shared with only one other Englishman, the late Mr. Herbert Spencer. At that time I was acting Chairman of the British War Mission, having been appointed by the War Cabinet to that position between Lord Northcliffe's departure and Lord Reading's arrival. I was able therefore to speak on all supply subjects with the weight of that official position. The dinner was in honour of Mr. Bainbridge Colby of the Shipping Board, who had just returned from Europe: Mr. Gerard, the former American Ambassador at Berlin, was also one of the principal guests. There were some 1,000 guests present. I ventured on that occasion to put forward my views on the importance of ships and oil, and to urge that the waste in luxurious use of automobiles should be stopped. I drew a picture that might be seen any day upon the great Fifth Avenue in New York or any of the great thoroughfares in and surrounding the large cities of America, viz. of the throng of many thousands of motor vehicles requiring skilled labour and valuable material for their construction, repair and driving and largely used for luxury and convenience. At the same time even on the American side of the Atlantic there was an urgent demand for vehicles to bring shipyard and munition workers to their places of work—on the other side of the Atlantic there were similar needs and in addition there was blood-red war and the ceaseless vigil of the ships upon the seas.

I made a suggestion which was warmly supported by Mr. Gerard and Mr. Colby, viz. that an immediate step could be taken to utilise the chassis of pleasure cars of the second or third year to provide small motor buses for transport of workmen and to set free skilled workers for engineering and general munitions service. After the dinner a large number of car owners wrote to Dr. Tucker, the Secretary of the club, expressing their willingness to put their cars at Government disposal for conversion. On this occasion and

many others, I found that there was in America, combined with a shrewd business view of a situation, a warm response to any genuine appeal.

This movement was happily strengthened by the action of the U.S. Government in diverting automobile factories from their ordinary work to that of producing the Liberty engine for aeroplanes and other war work. At a later stage came an increased demand for motor spirit in America for heavy lorries for military purposes and in relief of congestion on the railways. The Petroleum War Service Committee then appealed to the public to reduce consumption for purposes of pleasure. Later still, the U.S. Government called upon the people voluntarily to forego Sunday "joy-riding." This was an undoubted hardship, as it is the universal means of recreation in America for the working men to take their families on Sundays in their Ford cars into the country or down to the sea coast. Nevertheless this sacrifice was cheerfully accepted, as it had been long before in Europe.

Americans are warmly to be congratulated as are our own people and those of France and Italy on voluntary co-operation in such measures for the common good. In this connection I had much satisfaction in reading a statement of Mr. Mark Requa's at the Machinery Club in New York in October last, viz. that the first effect of "gasless Sunday" was to make it possible to load ten cargoes of motor spirit, a total of 500,000 barrels or, say, 70,000 tons, for Europe that otherwise would not have gone. This is a matter of hearty congratulation to all concerned. For my own part I could not help feeling some little satisfaction that I had been at any rate on the right track from the outset, and that our American friends were viewing the matter from the same standpoint that the Allies had adopted in Europe.

I must tell you here that the excellent market for gasoline stimulated invention or at least imagination in America in the direction of attempts to find some substitute at about 1d. a gallon for gasoline, which in that country had risen from 4½d. to about 1s. 2d. per gallon.

There was one inventor in particular, whose experiments were to some extent checked by engineers, who appeared to be able to obtain results from small quantities of specially prepared liquids, the formulæ of which were only partially revealed, mixed with large quantities of water. Efforts in the law courts and elsewhere, and some of them of a diverting character, were made to obtain the secret of the mysterious green or pink liquid, which gave to simple water a motive power hitherto undreamt of.

As sideline activities, apart from certain matters such as occasional assistance in the recruiting of British and Canadian subjects in the U.S.A., I was able to follow up in a general way the work that was being done in America in respect of the construction of concrete ships, also of barges intended for the conveyance of oil in bulk, and of the construction of concrete reservoirs for oil storage. I had much assistance in these matters from the U.S. Government Departments concerned and from American civil engineers and shipbuilders, also from Sir Henry Japp, Colonel Abbot and Mr. Goodall, of the British War Mission. Briefly, I may say as regards concrete vessels that I was on board the first large concrete barge for oil carriage, when the bulkheads were tested with satisfactory results. I understand that the vessel was successfully used for harbour service for carriage of oil in bulk. I do not know of any seagoing tanker built of concrete. Storage tanks of that material have been successfully constructed for heavy oils both in America and in this country, though it is fair to say that not all the American tanks had been a success. In conjunction with Engineer-Commander Nibbs, of the British Navy, I gave much attention also to interesting experiments which Mr. Lindon Bates, an American engineer, conducted in regard to the use of pulverized coal for marine purposes, either by itself or in combination with oil. Pulverized coal is largely used in America in blast furnaces and cement works and to a small extent in this country in cement works, but had not been previously tested for marine purposes. The experiments were still proceeding when I left America, and I can therefore express no opinion as to whether all difficulties, particularly of the relative permanency of suspension of coal particles in oil, can be overcome, so that some economy of oil for marine purposes may be effected by partial substitution of coal in suspension in fuel oil in a pulverized form.

At this point it may be said that if all our Petroleum problems did not find absolute and complete solution, nevertheless a remarkable measure of success was achieved, and all the essential requirements of the British, American, French and Italian Naval, Military Air Force and industrial services were met, although it may be admitted there were times of great anxiety. In the summer of 1918 in spite of all losses of ships and oil, the situation of the reserve stocks in Europe was 100 per cent. better than had been the case twelve months before and the earlier causes of anxiety were practically removed.

I have mentioned a number of individuals, Government Departments—British and Allied—and commercial Companies who con-

tributed to that great result. I have left to the last, however, a reference to the onerous labours of the Fourth Sea Lord of the British Admiralty—Admiral Lambert and Admiral Sir Hugh Tothill have held that post in succession during the war and their responsibilities for work of so vast a scale can only be appreciated by those who have inside knowledge. Its results and those of the labours of the Engineer-in-Chief of the Navy, Admiral Sir George Goodwin and his colleagues, can be gauged to some extent by all who know what the British Navy has been in this war and what part it played in the final triumph of the Allies. If we think of the services of the Navy alone in respect to safe transport of fuel overseas, their labours have been of the highest importance. Without going into details one simple fact speaks eloquently, viz. that about 250,000,000 tons of coal from mines of the United Kingdom for all purposes and about 30,000,000 tons of oil from all sources to all ports of the Allied countries in Europe have been safely transported overseas in the 4¼ years of the war. I have gone over now the problems that confronted us and the methods by which they were overcome. The case was a difficult one, but as the doctors say, "it yielded to treatment." The result was a record of co-operative work on the part of many individuals. The chain was a long one. Petroleum technology furnished many links in that chain; the pioneers, the geologists and explorers and drillers who were seeking for and testing new fields; the workers at the derricks, the pumping station and the pipe lines, the skilled staff in the refineries who had to vary their methods to produce the altered proportion of products according to the specifications and the business men unwearied in their application to duty in the offices of the oil Companies and the Government Departments. On both sides of the Atlantic naval architects, shipbuilders, engineers—a long array of professions—and last but not least came the sailor. There was no weak link in that great chain of workers, but the strongest link was the skill, courage and persistency of the sailors who, as Admiral Sir David Beatty recently said, "Nothing daunted by submarine or mine, maintained the traditions of the race, and no ship ever failed to sail for want of a crew." And what was the cause for which this effort was expended? To maintain the allied navies, the military force and the air force and to support them in their efforts to secure that freedom might not perish from off the earth.

I may now turn, if your patience will permit, from the problems of the past to those of the future.

So far as overseas transport of oil is concerned, it may reasonably

be expected that there will be sufficient tonnage available for the future. The seas are being cleared of mines, the German submarines are in the hands of British ship-breaking firms—the convoy system which was so great a success is no longer needed and voyages need not occupy more than the normal time. There will always be, however, in connection with the provision of tank steamers, the difficult question of how, by private enterprise, the tonnage shall be sufficient, with a reasonable but not too large a working margin to draw upon when the supply of oil happens to be suddenly increased and needs to be absorbed in markets beyond the limits of pipe lines and tank cars.

The most suitable sizes of tankers and types of propelling machinery are matters which experience will settle. It does not appear probable at present in light of comparative cost and relative efficiency that the concrete ship will compete with that of steel for overseas work. There is likely to be some effective use, however, for concrete barges for harbour and river work in countries where local conditions are favourable, *e.g.* where sufficient numbers of such craft are required in neighbourhoods in which an adequate supply is available of the principal concrete-making ingredients and of suitable labour.

In regard to concrete reservoirs as compared with steel tanks there will undoubtedly be some use for concrete, but in this case also according to local conditions and relative cost and the importance or otherwise of placing tanks wholly above ground or partly under ground. Although in one or two instances concrete tanks have been used with some degree of success for storage of gasoline, their use at present is likely to be restricted to storage of the heavier oils. The Admiralty have lately permitted the publication of particulars of their great oil reservoir constructed in concrete at Rosyth on the completion of which the Civil Engineer-in-Chief of the Navy (Sir Alexander Gibb) and the Admiralty Director of Works (Mr. T. Sims, C.B.) and their colleagues are much to be congratulated.

Increase of the margin of tank storage in this country, whether by Government or private enterprise, is obviously of high value for an imported product to enable advantage to be taken of market supplies and favourable freights, as well as to hold a reserve against temporary shortage of supplies. Sir Marcus Samuel in a recent speech pointed out that it now happens that storage may sometimes be so full that fresh cargoes cannot be landed.

The troublesome questions of oil supply are not therefore likely to be :—can it be refined or transported and stored, but will supplies

be forthcoming, and can the world's demand be met, and if so, from what sources?

In the paper which Dr. Ormandy recently read to you on the subject of motor transport, you were given the principal statistics relating to the world's supply of petroleum and demand for that product, and also of the number of vehicles which depend on petroleum for their propulsion. The latter figure is indeed striking. America possesses upwards of 5,000,000 of such vehicles. In 1917 it was estimated in America that there was one motor car to every nine persons in that country. At a rough estimate the rest of the world has about 1,000,000 such vehicles in use. In 1917 America alone had a power of production of automobiles of nearly 2,000,000 per annum. The standardised methods, some of which I was able to inspect, at such factories as Fords at Detroit, enable an immense production to be attained. Before the war, and particularly during the war, standardised methods of production were of course well known in engineering factories in this country, and we owe to such methods much of the wonderful output of munitions attained under the guidance of the British Munitions Ministry, and of machinery and mechanisms required by the Admiralty and other departments. I doubt, however, whether we have anything quite equal to the system which Henry Ford employs in his engine fitting shop, where an empty crank case starts on its journey down the shop on a slow-travelling carrier and arrives at the other end as a complete engine. The component parts arrive *en route* from right and left, usually in pairs, by means of overhead travelling wires from which the workmen take them down and fit them in place.

The increase of motor transport in agricultural districts and the transformation of farming in some branches at least into an engineering profession, must cause still further requirement of petrol beyond the large quantities already produced amounting in America alone to about 8 or 9 million tons per annum. The possibilities of the use of aircraft for commercial purposes have been put before the country by Lord Weir and General Seely, and this service will need a large supply of high-grade spirit. We already see the air bus in use for special purposes and one of its future uses may, we hope, have a special interest to Petroleum Technologists, in exploratory geological and drilling work in the search of oil in countries where land journeys are slow and toilsome. Whilst then the market calls insistently for the lighter fractions—gasoline and kerosene—it may be expected also that the demand for heavy residual oils for marine purposes will be largely increased up to the full limit of the supplies that can be made available.

The advantages of oil for marine purposes—for higher efficiency for saving of labour, and in war circumstances for actual saving of life—have already been alluded to in this paper and have been frequently demonstrated by high expert authority.

So far as substitutes for petrol are concerned, Dr. Ormandy has drawn your attention to one possible source of relief, if cost of production and available raw material so admit, viz. industrial alcohol largely used in France and Germany. Without entering into a detailed examination of this subject which Sir Boverton Redwood's Committee with Mr. Shrapnell Smith as Hon. Secretary is now engaged upon for the Government, it may be said that if economy of production can be obtained, various vegetable products will doubtless be utilised to provide spirit which probably, in combination with petrol or a coal product such as benzol, will be a useful addition to the world's supply, and it appears not impossible that some of the factories and methods which have been developed to produce propellants of high explosives for ordnance purposes may be turned to account for the production in question. I have already mentioned that many minds are turned towards searching out formulæ for synthetic production of cheap substitutes for gasoline. One thing may be said of all such research and possibilities—whatever discoveries short of the miraculous may be made—there is likely to be a commercial demand for every ton of petroleum that can be produced, refined and transported. Some years ago Mr. Deterding told me that his faith in the virtues of oil as a source of power were such that he had the greatest confidence that petroleum products would always find their market. Admiral of the Fleet, Lord Fisher, used to sum up the merits of oil in picturesque phrase as the "Oxo or Bovril of power."

If it be assumed for the moment that sufficient crude oil will be forthcoming to meet the demands for both the lighter and heavier fuels, there will undoubtedly arise a competition between the two. In order to meet the demand for gasoline "cracking processes" are, as I have pointed out, frequently carried to a point at which the available supply of heavier fuel is diminished. That diminution has to be made good by larger recourse to the heavier oils from Mexico and elsewhere, which necessitates special attention to questions of sulphur contents, and to preservation of a fluid condition of heavy fuel oil at low temperature. Obviously a stimulus will be given to the present tendency of engineers and inventors to adapt motor engines for the use of fractions heavier than gasoline, as well as to the greatest possible economy in the use of heavy fuel. It is of course too well known to need emphasis here, that the present

system of burning oil under boilers, whilst economical as compared with coal, consumes about three times as much oil as is necessary in engines of the Diesel type. Petroleum Technologists are, as Lord Moulton recently reminded us, greatly concerned in all questions relating to the economical use of fuels. Economy in methods of use is primarily the function of the engineer; whilst production of the aggregate quantity of fuel or variations in refining to produce the desired proportions of various grades of oil is for the fuel specialist; but there is no gulf between the two, and each needs to know something of what the other is doing or would like to do. Similarly there is room for all kinds of fuel as well as of methods of the production of energy. Electricity does not supersede gas, nor does oil put coal out of business. There is room for both.

No opinion of mine would be of the slightest value as to the line of possible engineering developments, accordingly I offer none. It will be of general interest, however, to Petroleum Technologists to see whether the Diesel type of engine comes into wider use on land and in ships, or whether gas turbines may eventuate, or electric motors be more extensively used. In any case a fuel will be necessary, and oil will have its advantages in storing and handling as well as in the flexibility, economy and efficiency of use that will always give it a high relative importance. It may be expected that the near or distant future will bring forth many new methods of propulsion of ships and the driving of machinery, but one can hardly conceive at present of any method that would not involve a large, although it may be hoped, a far more economical, fuel consumption.

In America much attention is paid as is the case in the British Admiralty, and I have no doubt in British industrial enterprises, to a study of the comparative merits of various fuels with a view to getting the best results from every pound of coal or oil. A fuel engineer is frequently attached to large works in America. In this country the subject is receiving, as you are aware, special attention at the hands of Sir George Beilby and other eminent experts.

I come now to the final stage of my subject. Whatever changes may occur in machinery and methods of power production, whatever partial substitutes for oil products may come into use, the possible extent and duration of the world's oil supplies is likely to remain for as far into the future as any of us can foresee, not only an evergreen and ever interesting subject of discussion where petroleum experts most do congregate, but a question of abiding practical interest. There have been as a rule two schools of thought in regard to the extent of the world's petroleum supplies. The producers of oil for the most part, but with exceptions, hold a comforting faith

and one for which they can point at least to past experience, viz. that because from the time when oil became of importance the world's increasing need has been met by the fresh supplies which man's enterprise has drawn from nature's resources, therefore this will always continue to be the case. Scientific investigators as a rule who base their calculations on geological formations, and data of past production from formations of a particular character usually take a more sober and less optimistic view, and there is as yet no means of deciding authoritatively between the conflicting conclusions of experts.

In the address, to which I have already referred, delivered by Mr. Mark Requa in New York in October last, will be found an extremely interesting review of this question. He emphasises the fact that whatever new fields of supply may be found a policy of conservation or economy of use must be continued. He expresses the opinion that America may have reached the zenith of its oil production, as oil producers have been very ambitious in developing supplies, and have evolved methods of production which have reached a high degree of perfection. As a consequence American oil fields have been more completely worked than those of other countries. As regards production in his own country he makes special mention of the recent opening up of the Ranger field in the west of the Texas State, which he evidently regards as of great promise—an opinion which was expressed to me in the early part of 1918 when I was at Houston, and met one or two oil men who had just returned from the Ranger district. He also sees a bright spot in production from shale in the U.S.A. He says there are other countries in which oil fields have not yet been developed. The geological survey department of the U.S.A. compute that about 40 per cent. of the entire known petroleum sources of the country have been exhausted. On the assumption that additional oil areas of equal productivity to those already known, will be discovered and worked, a life of 30 years only is calculated for American oil supplies excluding Mexico. He agrees, however, that there may be increased production in Mexico and other countries.

Eastern countries lying very near to the cradle of the human race seem not unlikely to be a possible field of production. A future Academy picture may show an oil rig in the Garden of Eden. You had a paper read to you not long since by Mr. Busk and Mr. Mayo on the geology of the Persian oil fields. I have always a vivid recollection of the description which Sir Boverton Redwood once gave me of the work of the pioneers in that region, Mr. Reynolds

and others under Mr. D'Arcy's auspices. Their work and that of many others whose names will occur to you furnishes evidence in support of what Mr. Greenway said at your annual dinner, that the Britisher is as capable as any other of pioneer work in lonely surroundings. The work on oil fields near to civilized centres is far different from that which has to be carried on often in trying climates and in remote districts. Happily petroleum and mechanical developments, marching hand in hand in the production of swift motor vehicles and in aircraft, are bridging over distances, so that the seas and deserts and even the mountains are no longer the serious barriers that once they were.

In April, 1838, just 81 years ago, the first voyage of a steamship the "Syrius" was made across the Atlantic. The voyage occupied 22 days. An aeroplane whose fuel and methods of propulsion are the last word of the petroleum and engineering industries can fly from London to Bagdad in less than half that time, and it seems probable that the year 1919 may see an air voyage across the Atlantic successfully accomplished in a time which will be counted by hours rather than days. On one point the optimists and those who take the less sanguine view are generally agreed, viz. that it is improbable that nature is reproducing oil in the bowels of the earth at the rate at which man is drawing it forth. Therefore whilst new fields of large productivity may be expected to come into bearing the duty of wisely conserving and economically using Nature's supplies is incumbent upon us all.

Some conclusions of a general nature may then be deduced by way of summing up:—

(1) There will be a large increase in the world's demand for petroleum products, for ships, motor vehicles, tractors and for aviation.

(2) The demand for some years to come can be met by man's enterprise in discovering new fields and bringing them into production.

(3) Every method of conservation and avoidance of waste of petroleum must be pursued, and every mechanical device adopted that will tend to the same ends.

(4) That oil products from coal, cannel and shale and vegetable substances will sooner or later be in increased demand alongside of petroleum derived directly from the earth.

(5) That in all these matters there will be a great field for scientific research and for the exercise of technical skill. Consequently practical training in and the acquisition of wide and deep knowledge of all branches of the petroleum industry will be essential; the producer and the user of fuels will need to keep very close together.

One general conclusion can be advanced with some degree of confidence, viz. that progress never ceases. The world never takes an irrevocable step backward, although it may recoil, to step forward the more surely.

I am indebted to Sir Robert Hadfield for a translation which he has sent me of an address delivered quite recently in Berlin by a German engineer, in which the work of the economist in the utilisation of fuel is alluded to, and specific instances of economies are quoted from German experience in munitions production. The same engineer also gives utterance to some sound doctrine of the increasingly important part which technical skill is likely to play in the world. The Editor of the Journal of your Institution (Mr. W. H. Dalton) in the December issue has spoken to the same effect, and made some practical suggestions.

The work that is done by the world's great thinkers as well as that of an imaginative, creative and artistic character is admittedly often of as high value as, or even higher value than, what is usually regarded as of a practical, technical, scientific or research character. More and more, however, the world needs the practical man, using that term in the best sense of one skilled to do constructive work whether mechanical or otherwise. But generally speaking the practical man will always have a higher proficiency even as a specialist if his specialized knowledge has a wide basis of more general knowledge and experience, and if he does his specific work with breadth of vision. It is one of the aims of your Institution to further the acquisition of that broader vision and to keep all branches of your profession in touch with each other and with cognate institutions.

At your annual general meeting on 25th March, Dr. Ormandy alluded to the possibility of extending the membership of your Institution by arranging for your library to be more accessible. This is a subject which I have no doubt will engage the earnest attention of your Council; likewise the even more important matter to which Mr. Greenway made reference in his speech at your annual dinner, viz. the action which the Institution may be able to take in association with the great British Oil Companies for the improvement of the training of Britishers as oil men.

It hardly needed the war and its experience to demonstrate to the British Empire the importance of oil to our development and protection. It is well known to you that only a small proportion of our supplies is at present obtainable within the Empire, but the operations of British Oil Companies are extending, and it goes without saying that all the principal British Companies are

interested in selecting and assisting to train Britishers for their work, and have in fact done a great deal already in that direction.

Now that the war is over I trust that the Institution, which is, of course, in close touch with the nature of the training given at the Universities in geology and chemistry and at Birmingham and South Kensington on more definite oil work, will take this matter in hand. The Companies alone can find a field for practical work and completion of training. At the same opening of a recent issue of *Oil News*, in which Mr. Greenway's speech is reported, will be found a letter from Mr. Wilfred Gooday dealing with the same subject, viz. the necessity of training men of British nationality for practical oil work of every branch. Mr. Greenway indicated that your Institution has already contemplated the setting up of a sub-committee to co-operate with the Oil Companies in formulating a practical scheme. As the Editor of your Journal points out, one proposal that will come up for discussion is likely to be the possibility of travelling scholarships to enable first-hand knowledge to be gained in the fields where oil is obtained.

In conclusion—a world without petroleum and therefore without petroleum technologists is at present unthinkable. Therefore your Institution may go forward in good hope improving its facilities and the opportunities of its members to increase their individual knowledge and to add at the same time to the aggregate of the world's knowledge, and thereby to promote the supply of products which contribute to the welfare of mankind.

The Chairman said that on the principle of speeding the parting guest he desired first to be allowed to say on behalf of the members a few words of admiration of the manner in which the immediate Past President during his two years of office had discharged the duties entrusted to him. Those who had had the opportunity of attending the General Meetings, and who were present at the recent successful Dinner, would know how good a Chairman Mr. Greenway had been, but it was only those who had been Members of the Council of the Institution who were in a position to appreciate the extent of the services which Mr. Greenway had rendered to the Institution. Although, as Sir Frederick Black had said, the ex-President had commercial interests and business duties of a most onerous character, such as might easily have daunted the energies of even the bravest men, he nevertheless found time to give unremitting attention to the work of the Institution, and he was ever mindful of its interests. He well remembered when he saw the President in bed immediately after the operation he had to undergo

that his first question was : " How is the Institution progressing " ? and evidence of his sustained interest in the affairs of the Institution was given by his proposals in respect to the training in petroleum technology. He was sure that, although Mr. Greenway was no longer the President, the members could continue to look to him for valuable guidance in carrying on the work which lay before them.

It was not customary to discuss a Presidential Address. Such an Address was by common consensus of opinion very properly regarded as lying on an exalted plane far above the reach of any ordinary criticism. But that, he was sure all the members would agree, should not be allowed to debar them from expressing, as he now did, on their behalf, their very deep admiration of the most interesting, thoughtful and eloquent address to which they had just listened. In consequence of his age, he had probably heard more Presidential Addresses than most of the members, and he could conscientiously say that he had never listened to any address which had so favourably impressed him from every point of view. During his recent sojourn in the United States Sir Frederick Black had, in connection with his highly responsible official duties which he had so successfully discharged, been called upon to address many large audiences, and those who had been on the other side of the Atlantic knew that the level of public speaking in the United States was high. It might therefore be taken for granted that he had undergone what might be described as a process of education. Gifted by nature with the capacity for clear thinking and vigorous expression of the views that he had formed, Sir Frederick had, as the outcome of that practice, developed into an orator, and he was sure that his only anxiety at the present time was how to reconcile that development with the proud boast of the Navy that the Service to which he belonged was the silent Service. But circumstances altered cases, and they were all quite satisfied that Sir Frederick Black would never be found talking about matters which ought not to be made public. It was sufficient for the members to know that they had in their President a man exceedingly well fitted to express the views that they might at any time desire to put forward. He was sure the members would agree that the Institution was to be most warmly congratulated in having secured the services as President of a man so well qualified to occupy that position as Sir Frederick Black, and on their behalf he tendered to him their most cordial thanks for the address which he had been good enough to deliver.

The President, in acknowledging the resolution, said that Sir Boverton Redwood had stated that he knew how to speak and how

to be silent. He had done sufficient talking for that day, and he proposed, therefore, to take upon himself the functions of the Silent Service, and merely thank the members for the very kind reception that had been accorded to him. He hoped at the end of his term of office he would have some record of work to show, which would probably not be comparable with that of his three predecessors, but that at any rate he would then be able to say that the Institution had gone forward and not backward.

The meeting then terminated.

Thirty-Ninth General Meeting.

This Meeting was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C. 2, on Tuesday, 20th May, 1919, Sir Frederick W. Black, K.C.B., President, occupying the Chair.

The Members of Council present were Messrs. H. Barringer, E. H. Cunningham Craig, Dr. A. E. Dunstan, Mr. Arthur W. Eastlake, Dr. W. R. Ormandy, Mr. T. C. Palmer and Sir Boverton Redwood, Bart.

The President remarked that the authors for that evening needed no introduction to the members. Their paper was a very brief one, and it had evidently been prepared with the object of promoting what the Institution always desired at its meetings, namely, a really good discussion on technical matters. The paper contained what our American friends would call a good deal of "pop" and a good deal of "snap," and the great merit of a technical paper was the "pop" and "snap" it produced in those who wished to take part in the discussion.

The following paper was then read :—

The Chemist and Engineer in Relation to the Petroleum Industry.

By F. Mollwo Perkin, Ph.D., F.I.C., F.C.S., and T. C. Palmer, Assoc.M.Inst.C.E.

The distilling and refining of petroleum, and the treatment of the various by-products is essentially an industry requiring the combined services of the chemist and engineer. In its ultimate stages perhaps more depends upon the engineer than the chemist : possibly one might say the same of the initial stages, because drilling for oil or mining for shale is entirely the province of the engineer. When, however, the oil or shale has been obtained, the

chemist must examine the products, and advise the engineer as to the methods of refining to be adopted.

The devising or improving of a process for treatment of any particular oil, shale or coal rests with the chemist, and the designing of the necessary apparatus on a laboratory scale is also the province of the chemist. The designing of the plant for carrying out the operation on a commercial and manufacturing scale requires the services of a skilled technical engineer of general experience, with a knowledge of the general principles of chemistry. As for the most suitable materials to employ for any required process, the chemist and engineer must collaborate.

In many instances the chemist is his own engineer, at any rate so far as to outline in a rough way the plant he requires, leaving it to the manufacturers to prepare the finished drawings of the apparatus, and to carry out the manufacture and erection of the plant. During the erection close collaboration between the chemist and engineer is essential.

The engineer applies his engineering and chemical experience to the problems of providing suitable apparatus and plant for any required process, in co-operation with the chemist who has worked out the process, as it is impossible, owing to the time required in the proper training, for a chemist to become a skilled engineer, or an engineer to become an efficient chemist, but with two suitable men working together in their respective spheres, one obtains the best combination for carrying out chemico-engineering problems.

The engineer should also have the necessary judgment and experience to enable him to consider the various problems as they arise, so that he may be in a position to arrive at definite conclusions as to whether the estimated yields and cost of working the process which the chemist has suggested will warrant the proposed outlay on plant.

In designing a working plant the chemist and engineer should have in view the following essential points :—

(1) Simplicity in design and construction with the minimum of repairs, arranged so that when repairs are necessary they can be carried through quickly and easily. They must also bear in mind that there are such things as depreciation and maintenance and repair cost to consider, and that it is necessary to employ all possible labour-saving devices so as to keep down the expenses of working and running the plant.

(2) The fuel question is of the utmost importance, and the adoption of a good economical system of heating and power best suited for the particular purpose requires to be very carefully

considered in connection with local conditions and requirements. The chemist is apt to forget that the generation of steam costs money, and this cost may be so high as to completely put out of court an otherwise satisfactory process.

(3) Regulation and perfect control of temperatures with automatic recording devices should be used where possible, as the scientific control of any operation largely depends on accurate measurements and records being regularly taken.

Sources of loss in boiler house and other equipments in connection with refineries, which are more or less avoidable, are: radiation from brick setting; incomplete combustion; leakage of air; excess of air through fuel bed (where coal is used); dirty heating-surfaces; imperfect coating of steam mains. In order to detect and prevent these losses, CO_2 recorders, draught gauges, efficiency meters, steam flow meters, water meters and temperature recorders should be used where possible. It is also important to carefully watch for leakages in steam and water mains.

Boilers should be worked at their most efficient load, and, as the cost of starting up is high, the fires should not (except for cleaning purposes or repairs) be allowed to drop or go out even for short periods.

Fuel-weighing or measuring should be employed, as considerable economies can be effected thereby. We consider that it would be advantageous if fuels—both solid and liquid—were always bought on a calorific-value test—that is to say the price should be dependent upon the calorific value. The quality of fuel oils as put upon the market leaves very much to be desired, as they frequently contain excess of bitumen and free carbon. Sometimes one finds in the heavier oils considerable quantities of water in suspension, which interferes with the firing.

To maintain efficiency, records of performances should be maintained, as every condition of operation varies more or less. Observations showing the distribution of draught give valuable information concerning defects or unfavourable conditions.

Superheaters and regenerators are specially important, and, in the case of steam turbines, every 10° F. superheat lowers the steam consumption by about 1 %. It is desirable that losses in other parts of the installation should also be carefully considered, and kept as low as possible. The furnace produces the heat, and the boiler or generator utilises it. The performances of both are quite distinct; the resulting efficiency depends upon the care employed in keeping accurate records, and in making proper use of such records when they are obtained.

Where no regeneration is used, the amount of heat which is wasted in the flues and chimney may be colossal.

We might here give an example of heat-saving and utilisation. In a certain oil-cracking process, the oil was pumped through a heating system which it left at a very high temperature (about 600° C.), the oil being kept in the liquid state by pressure. In order that this oil could be distilled and treated, it was necessary to cool it before reducing the pressure. It was therefore passed through coils in a boiler, where they were immersed in water. By this means the oil was reduced in temperature to about 170° C., and there was no difficulty in maintaining a pressure of about 60 lbs. of steam, sufficient steam being obtained for refining operations. A further saving was made by passing the partially-cooled oil into a still where the light fractions (i.e. those below 170° C.) were given off without the addition of further heat.

Other examples of heat exchange between condensers and coolers employed on a large scale in the oil industry are :—

Surface condensers for condensing vapours and for cooling liquids without the cooling medium coming in direct contact with the oil or liquid, the exchange of heat taking place through metal surfaces.

Condensers may be constructed of tubular or other systems so arranged that the vapours pass through the tubes and the cooling medium on the outside, or *vice versâ*.

Frequently the cooling is effected by means of air instead of water, in which case the air is blown or drawn over the cooling surfaces by fans or other suitable means. Water is generally adopted for cooling, although in the production of high-boiling-point oils the exposure of the cooling surfaces to the air has been found sufficient. It is necessary sometimes to increase the temperature of the condensing water, in order to prevent solidification of wax or other material in the cooling pipes. This can be done by using water which has been employed for cooling condensers, and has thus taken up heat.

The cooling of a hot liquid by means of a colder liquid, or, what is the same thing—heating a cold liquid by a hot one—may be effected in two ways :—

1. By passing two liquids at a high velocity continuously in opposite directions (one being inside a tube and the other outside), or by bringing the whole quantity of liquid to be cooled periodically into a vessel and allowing the cooling liquid to flow round the external walls or through tubes, until the liquid is sufficiently cooled. This operation may be expedited if the liquid to be cooled is made to travel at a fair speed over the cooling surface, or the

cooling surface continually moved through the liquid, as the very small difference in temperature existing causes only a slow circulation otherwise.

2. In the distillation of oils and other similar operations, the hot oil discharged from the stills passes through coil pipes fixed in cylindrical vessels, through which the crude oil-supply to the still passes, and is heated on its way.

We might here mention some of the points in which close collaboration between the chemist and engineer is required.

The basic principles of the design are arranged by the chemist on ideal lines, and these lines should be adhered to as far as possible. Should the engineer, however, find that the plant as originally suggested cannot be carried out conveniently, he must then consult with the chemist with the view of making the necessary alterations.

Unobtainable Conditions.

a. *Pressure.*—As laboratory apparatus is so small, and enormous pressures are often used, there is no difficulty in making suitable apparatus on a small scale, but when a commercial unit is required, say, 100 times larger, there may be difficulties in the construction. Consequently the chemist may have to be satisfied with smaller vessels and more units than originally asked for. If the pressure can be reduced, and the time for the reaction increased so that it is less violent, it may be possible to retain the larger vessels.

b. *Temperature.*—Very high temperatures can be obtained in the laboratory with electric heating, whereas the commercial plant may not be able to draw upon a supply of electricity, but by a slight modification in the process it may be possible to use an existing supply of producer gas, or, if it is a large installation, to put in special producers.

c. *Power.*—The laboratory power is generally personal manipulation—that is hand power. On the large scale power is one of the most important factors to be considered, as the cost of the finished product necessarily depends to a large extent upon this factor.

d. *Effluent gas and liquor.*—Often a plant cannot be installed on account of the probable pollution of atmosphere and river, and even if a purification plant is suggested, the consequent extra space, power, etc., cannot be obtained; or the cost of purifying the effluent and rendering it innocuous may so add to the total cost of the process as to make it not commercially workable.

e. *Human Element.*—Occasionally a process fails because too much is demanded of the operators who may be working in a bad

atmosphere, or the operations may be so delicate that a large quantity of valuable material is spoiled by the least variation in the conditions.

Uneconomical Conditions.

a. *Capital Cost.*—As laboratory chemical apparatus is generally glass, porcelain, silica or platinum, the question of corrosion does not present any trouble to the chemist, yet this is the most important feature from the engineer's point of view. Sometimes an acidic or other corrosive process requires such a large outlay of capital for plant made of non-corrosive material, that the interest and depreciation would not warrant the outlay. On the other hand it may be possible to modify the process.

b. *Power.*—Some processes may continuously demand such an amount of power that it is impossible to work them at a profit. Again, others require large quantities of power for short periods, and consequently the cost of power plant required only for intermittent work becomes a burden on capital cost. Varying the process to obtain a more equitable power-distribution is a scheme often resorted to with success.

As in this country we require cheap fuel and power for the development of our industries, we must obtain them from coal, cannel, shale or lignite—possibly from peat. Now there are only three methods for obtaining cheap power from these sources :—

1. Actual burning under boilers.
2. Carbonisation with production of oil.
3. Burning in a producer.
4. Burning as tar gas and coke.

In all probability a combination of the 2nd and 3rd will be found the best.

In all schemes for power production the closest collaboration between the chemist and engineer is essential. If the chemist cannot find a means of purifying the by-products of the second process, and of rendering them fit for commercial use, then no amount of skill on the part of the engineer will enable him to supply cheap power.

Working Temperatures.

The production of by-products from bituminous materials may either be by low-temperature or high-temperature carbonisation; the latter being the gas works operation, but this admits of many modifications. The low-temperature processes are more or less in their infancy—many of them have not yet left the cradle. It is

here where the chemist and engineer have a very difficult problem. The chemist, from his knowledge of the properties of coal and the action of heat under varying conditions, must co-operate with the engineer in the design of the retort or oven for carbonising. Even yet, after all these years of gas manufacture, we are woefully ignorant of the constitution and properties of coal. The erection of the gas works has been mainly carried out by the engineer, and the chemist has not been sufficiently in evidence.

A great deal can be learned from the important research work of Dr. R. V. Wheeler and Dr. Marie C. Stopes, whose most valuable monograph on the constitution of coal has recently been published. This is the work of the pure chemist, which no engineer could have carried out. In this connection the chemist has still to go further and put the facts concretely before the engineer, so that a process can be evolved for translating this knowledge to the national benefit. It must not be supposed that this can be done without a large amount of careful research both on the part of the chemist and the engineer. The oils obtained by low-temperature carbonisation are very different to those obtained from the earth by boring, and the methods of refining cannot therefore be the same. These oils approach the shale oils—that is, they contain a large amount of unsaturated hydrocarbons, and, like cracked spirit, contain also poly-olefines and similar bodies which have a tendency to polymerise and become gummy. Ordinary methods of refining will not remove these without at the same time destroying a large amount of the other hydrocarbons. Here, then, the chemist must carry out the research, and when a satisfactory method has been evolved, the engineer will co-operate to work out the most satisfactory plant to be employed on a large scale.

There is also the designing of the retort or oven so that the carbonisation may proceed evenly, and at the same time a good throughput be obtained. Close co-operation between the chemist and engineer is necessary here also.

Oil-Shale Distillation.

One of the most interesting examples of the foundation of an industry by the collaboration of the chemist and the engineer is to be seen in the distillation of oil shale as practised in Scotland. This industry was initiated in England by the chemist James Young in 1847, and then largely taken up in America. In fact when oil was first obtained by drilling, which resulted in the production of more oil than could be used, there were a large number of shale-retorting

plants in operation, but, owing to the competition of the natural oil, many had to shut down.

In the early days of shale retorting or distilling, very little consideration was given to economical production. The uncondensable gases produced from the shale were allowed to pass into the atmosphere. The ammoniacal liquors produced were considered of so little value that not only were they run to waste, but were considered an unmitigated nuisance. Then the industry entered upon a period, when, owing to the competition of American natural oil, economies had to be introduced or the industry go under. Economies and changes in methods of distillation and plant were gradually introduced, in which the exit of vapours was effected at the bottom of the retort instead of the top, and arrangements were made for utilising the uncondensable gases for heating.

Other improvements were made in the retort-settings so that the spent shale could drop out of the bottom from a combustion-chamber where the carbon was gassified by means of steam, and utilised for supplying the greater part of the heat for distillation. A large recovery of ammonia was also obtained by the same treatment.

The importance of sulphate of ammonia as a fertiliser was beginning to be realised, and its production practically saved the Scottish shale oil industry. Further improvements in process and plant were made at various times, the result at the present day being that we have an economical and efficient vertical shale-retort, heated by the uncondensable distillation gases, with producer gas as an auxiliary fuel, also mechanical devices for charging and discharging and removing the spent shale.

A study of the shale industry is a good example of the application of science and practice when properly directed, and shows the enormous importance of the combined efforts of the chemist and engineer as applied to the Scotch Oil Works.

Gasoline from Natural Gas.

Until within the current decade, the gasoline contained in natural gas was not recovered, this valuable source of light spirit being neglected. Engineers engaged in the petroleum industry have now adopted scientific methods, and very large quantities of light spirit are obtained from this source.

There are three methods that can be adopted for the extraction of gasoline from natural gas, viz.: compression, refrigeration and absorption, or by a combination of any of these systems.

It is well known that the cooling of vapours to a temperature

below that at which the air is saturated causes precipitation, in the form of rain or snow, and in compressing air it is found that by increase of pressure, moisture is deposited at atmospheric temperature. The same applies to hydrocarbon vapours present in incondensable gases, that is to say, gases which require very high pressures and low temperatures to condense them, because all gases have their critical point, none being absolutely incondensable.

To recover the necessary fractions, only such pressures and temperatures are necessary as can be obtained by a two-stage compressor, the vapours being heated by compression and cooled on expanding, and by using the cooled gas as an auxiliary cooler, the maximum of the required condensate can be obtained.

In the absorption-process, the vapours are brought into intimate contact with an absorbing medium, and afterwards recovered by means of fractional distillation and condensation.

Purification Processes.

Another concrete case of the collaboration of the chemist and engineer is illustrated in the process of purification designed by Dr. Edeleanu to remove unsaturated from saturated hydrocarbons. There is probably a great future for this process.

To work with liquid sulphur dioxide on a large scale, where hundreds of tons of material are used, requires the highest skill on the part of the engineer. There is also still a great deal of research work necessary on the part of the chemist.

There are certain standard methods of purification used in the petroleum industry—washing with sulphuric acid and alkali, and it is very difficult for the chemist to get out of the rut, and devise new methods. Any process for purifying on a large scale must be cheap, and the chemicals employed must not decompose any quantity of the hydrocarbons.

We have only to look at the difficulties in refining cracked spirit so as not actually to decompose the product. The difficulty is to get rid of the noxious compounds (which may only be there in small proportions), without also decomposing the main valuable products.

There is also still considerable scope for improvements in the refining of shale oil.

The chemist and engineer have, by collaboration, produced the various products of the petroleum industry; the question arises, Has the collaboration been close enough? Cannot better results and better products be obtained by a still closer brotherhood? These are certain problems of great importance which have to be elucidated.

1. How is sulphur to be removed from oils obtained from shales containing a large percentage of this element? We are here dealing with a very difficult problem. The shales are distilled at a more or less low temperature, which produces a large amount of unsaturated hydrocarbons, mainly of the olefiant series. Drastic treatment to eliminate the sulphur would probably also decompose the unsaturated hydrocarbons. It is for the chemist to devise a scheme for treating the oil, and he will then call in the aid of the engineer to design the plant.

It must be remembered that the sulphur is united with hydrocarbons, some of them of very high molecular weight. If these compounds have to be absolutely disrupted or broken down in order to eliminate the sulphur, the loss of oil will be very great.

2. Low-temperature carbonisation of coals and cannels also yields oil containing a large quantity of unsaturated hydrocarbon and polyolefines or substances which polymerise to form viscid or gummy materials, also large quantities of phenolic bodies. As commercial-scale tests are about to be made on low-temperature carbonisation, the chemist must devise suitable refining methods. The engineer will assist with the plant both for refining and for carbonising.

We might give many more illustrations where the most thorough collaboration of the chemist and engineer in the mineral oil industry is of the utmost importance, but we think that the two problems set out will be sufficient to illustrate our case—the importance of the intimate collaboration of the chemist and engineer. We consider that life is too short for the chemist to be his own engineer, or for the engineer to be his own chemist.

DISCUSSION.

The President, in opening the discussion, said it went without saying that the Institution was deeply indebted to the authors for their highly suggestive paper. Dr. Perkin had covered a very wide ground. The speaker had noted down some of the points, solutions of which he should be very much interested in seeing.

One came at the very end of the paper—that of getting the sulphur out of the shale oil. If the authors or anyone else could state how that could be done, they would reveal something of very great value. The whole subject of low-temperature carbonisation of coal was practically covered by the remarks Dr. Perkin had made.

On the point as to whether the engineer and the chemist in the

petroleum industry should be one person or two, he (the President) had no views to offer, but he thought a great many members of the audience might have opinions to express on that matter.

Dr. Perkin, like a great many other users of fuel, would like to buy his coal or oil by calorific value. That might be a very desirable thing to do, but there was a very genuine commercial difficulty, which did not arise from the prejudice or obstinacy of the seller of coal, namely, that there might be fuels that were of equal calorific value, but the one perhaps had a much wider range of utility than the other; that was to say, there might be a coal, for example, that was equally good in a locomotive and on board ship, and there might be another coal of practically the same calorific value which was much more limited in its use, and naturally there would be a difference in the commercial value of the two. He did not say that that circumstance necessarily prevented anyone who wished to buy fuel by calorific value from asking for it on those terms if they could get it, but there would always be a difference in market value due to that particular reason.

Where Dr. Perkin spoke of cheap fuel and the methods of using fuel, it might not be out of place if he were to say a word or two suggested by something which he had read in the daily papers a day or so previously, and also by some experiments which he had had the pleasure of watching in America, and that was the possibility of using coal in a pulverised form. Mr. Leonard Harvey, who had been in America with him at the same time and who had collaborated with him, had lately given a paper before the Iron and Steel Institute, which, according to Dr. Ormandy, was an extremely valuable and able paper. Dr. Ormandy believed that the subject was well worthy of study. The use of pulverised coal on shore in America was no new thing. There were something like ten or twelve million tons of coal used in that form. It was dried first, and then very finely pulverised, and it was used in cement works and steel works more particularly, and to a limited extent in locomotives; but the form in which he had been particularly interested in its use was when mixed beforehand with oil, and then sprayed into the furnaces through the burner, in the same way as oil alone would be. He did not think it was too much to say that the main difficulty of spraying, the choking of pipes and burners, had been more or less successfully overcome up to the time he had watched those experiments in America; but the question of how long the dust could be kept in suspension was a very difficult one. There was a particular formula which mathematicians and scientific men were familiar with, known as the Stokes law, by which, if one knew

the specific gravity of the coal dust and of the liquid, and one had perfect spheres of solid matter, one could tell within what time the solid would separate out. It was claimed in America that certain "fixateurs" could be used that kept the coal dust, especially if very finely ground, in suspension for quite a length of time, and he had seen a tank of that mixture, where the mixture had been kept, he thought, 8 to 12 weeks; but at the end of that time a very considerable proportion had settled out, and there was a thick gelatinous mass at the bottom of the tank. It was quite clear therefore that for marine purposes at any rate the problem in that respect had not been at that time completely solved; but possibly for land purposes, where one might re-agitate, that particular difficulty might not be serious. Anyhow, he did suggest that might be one very valuable means of economising our oil, especially for marine purposes. There was an adaptation of that system at the refineries which was just introducing itself in the U.S.A. Pulverised coal was there being mixed with the residual oil from the pressure-stills; that was to say, when the cracking processes had been carried as far as was economically desirable, the residual oil could be usefully mixed with pulverised coal and used under the stills, and it might be used perhaps for other purposes. Then he believed that the experiment went a little further. There was a mixture being made of that pressure-still oil, tar, and one or two descriptions of natural petroleum oil with a percentage of coal dust. He thought the point of saturation which was more or less feasible and more or less workable through the burner was something like 31 or 32 per cent. of coal dust, and the rest was oil with a small proportion of the particular fixateur, the nature of which had not yet been made known. That particular subject of coal dust mixed with oil, if the members thought it of sufficient interest, might possibly be pursued a little more in detail at a future meeting of the Institution. He hoped the members would not think he had led them off too much from the track which Dr. Perkin desired them to follow, but he thought this subject of coal and oil was pertinent to Dr. Perkin's remarks on the use and economy of fuel.

Sir Boverton Redwood remarked that on the whole he shared the view of the authors of the paper that, having regard to the progressive demand for the highest skill in the treatment of crude petroleum and oil-yielding minerals, with the object of obtaining from them the usual commercial products, it might be held that the services conjointly of the highly-trained engineer and the highly trained chemist were needed to obtain the best results. It seemed logical to take that view, looking to the circumstance that, as he

had said, higher skill was demanded now than had been formerly the case, and it was unreasonable to expect the highest skill on both sides of the scientific aspect of the question, namely, the engineering and the chemical, to be combined in one individual. But in expressing that view, he should like to say that in his opinion it was highly desirable that the chemist who had to take that sort of position should have some considerable knowledge of engineering, and conversely that the engineer should have at any rate an acquaintance with the principles of chemistry. Unless that was the case, it seemed to him to be hopeless to expect that sympathetic co-operation which he took to be essential to the sort of brotherhood to which the authors of the paper had referred. He emphasised that point with the object of going on to say that in his opinion the lesson to be drawn from what the authors had said, was that in the training of the student it was highly desirable that specialisation should not commence at too early a stage; in other words, that there should be an exceptionally good general foundation laid, that the student should have the opportunity of becoming something of a chemist as well as something of an engineer before he sought to know, as would subsequently be his aim, everything that could be known about that particular branch of science which he elected to make his speciality, be it engineering or be it chemistry.

He was glad that the authors had called attention to the need which existed for more general and more efficient scientific control of the use of fuel. It was extraordinary to find in many cases large amounts of money devoted to far less important branches of work carried out in industrial establishments. In many instances, which must be within the knowledge of most in the room, the governing factor in the employment of fuel, especially for steam raising, was the emission or non-emission of visible smoke from the chimney. He thought most of the members were aware that stokers who had been once bitten were twice shy in the sense that having once been fined for emitting a large amount of visible smoke, they pursued the policy thereafter of introducing so much air into the furnaces that there was no smoke, but that there was a very large waste of fuel resulting. In respect of the oil industry, it might be said that economy of fuel was the key-note of successful administration of the refining department of the business. Great economy had been introduced by the substitution of continuous for intermittent distillation, and within recent years more had been done in that direction by the adoption of the many ingenious systems of heat transference or interchange which were now in common employment in modern up-to-date refineries. But notwithstanding what had

been done, it had to be confessed that, taking the oil industry as a whole, in many parts of the various operations, progress had not extended far beyond the somewhat primitive methods of procedure of the early pioneers. He therefore warmly endorsed the statements of the authors that there were before the oil engineer and the oil chemist a great many most important problems which had yet to be solved before it could be said that the industry had been placed in a satisfactory position. He was quite sure that if the paper merely served to direct attention to the great importance of the subject with which it dealt, and to evoke the discussion which all were hoping to have from the large and representative gathering present, the authors would feel fully recompensed for their labours.

Prof. J. W. Hinchley said he had to offer some little criticism of the paper. Personally he respected both the authors of the paper, but he could not congratulate them on being before the times; he was rather inclined to think they were behind the times. But perhaps he was wrong in that respect. The title of the paper was "The Chemist and Engineer in Relation to the Petroleum Industry." There were heaps of chemists in the world, and he was certain that a particular kind of chemist was required in the oil industry. He was inclined to think in the same way that the paper dealt with a particular kind of engineer. The inference running through the paper was that any chemist and any engineer in the oil industry was what was being talked about. He contended that what had to be referred to was the oil chemist and the chemical engineer. There was enough work to do with regard to oil to occupy all the brains of any man on the chemistry on the subject, but he suggested that unless the engineer had been a student of chemistry and had a good knowledge of physics he would not make much of a job at designing oil plant. In addition to having a knowledge of chemistry he had to have a good knowledge of physics. It was all very well to talk about systems of heat transference; there had to be a scientific man to use them. The capital cost of much of our chemical plant in this country was double what it would be if there were a decent knowledge of chemical engineering. The sizes of plants which were used for different purposes were often very much larger than necessary, and a sense of proportion among different parts of the plant was very often as bad as a Chinaman would have, because any engineering firm was considered good enough to design and make chemical plants. Mr. Palmer was a chemical engineer, and his work was excellent. On the other hand, it had to be remembered that the manufacturing chemical engineer had not had much guidance, and there seemed a conspiracy in this country not to help

the development of chemical engineering. He stood that night to pioneer the study of chemical engineering. The Imperial College of Science had now been made a substantial grant, and had been trying for a long time to develop the subject of chemical engineering. There were huge questions on which the prosperity of this country depended which had to be dealt with by this particular kind of engineer; the chemical engineer. As the authors said at the end of their paper, life was not long enough, but it was long enough to train a particular kind of chemical engineer who would handle the practical problems of the oil industry. With regard to heat transference, and with regard to all similar questions, the subject had to be studied as a chemical engineering subject. If one wanted an alternator, for example, one would not go to a professor of physics and ask him to co-operate with a man who made steam engines to design an alternator. There were in existence at the present time men who could design electrical machinery and who could produce designs of efficient machines equal to any in the world, but we should not have obtained such machines had we had to depend on co-operation between the physicist and the engineer. Special men had had to be trained. The electrical industry to-day depended upon producing special men, electrical engineers. The oil industry of to-morrow of this country depended upon the production of special men, and he appealed to the audience to help in producing those special men by assisting to develop the subject of chemical engineering in this country. The Imperial College of Science had a course. The Battersea Polytechnic first started systematic teaching of chemical engineering. Manchester had started this year, and Birmingham was also starting; but a good deal of work had to be done, and a good deal of support was needed from the men who ran the businesses of this country. The authors had pointed out perfectly clearly that nothing was satisfactory unless it paid, and the most important problem to be dealt with was to make a business pay. He had very rarely come across co-operation between the chemist and the engineer—the sort of co-operation that was suggested in the paper—where there had not been an enormous waste of money in the process. He could take anyone round the country and show him derelict plant which had been designed by engineers at the suggestion of chemists. If those men had set to work and had spent a few months in studying the subject with which they were dealing—studying it in the chemical engineering laboratory on chemical engineering lines—that money could all have been saved, and a solution of the problem would have been arrived at just as quickly. He hoped the meeting would not imagine that

he was suggesting that the chemical engineer should supplant the chemist. The synthetic chemist, the analytical chemist, the experimental chemist were all required; but the man who designed the plant had to understand the physics and the chemistry of the operation. If the chemical engineer was defined as a man who designed and looked after the operation of plant to carry out chemical and physical operations on materials on a commercial scale, and if chemical engineering problems were dealt with as chemical engineering problems, immense progress would be made; but as long as they were dealt with merely from the point of view of producing (say) steam and power and not as chemical engineering problems, that progress would not be made. In order, therefore, in the near future, to make this country as prosperous as it had been in the past, attention had to be devoted to the subject of chemical engineering and its application to all industries—not only to the oil industry—in which a knowledge of chemical engineering was necessary.

Dr. Ormandy remarked that the authors of the paper rather led one to believe that they considered that a combination of the chemist and engineer which was worthy of the conjoint title of chemical-engineer was not something to be aimed for, as it was something impossible. If such a supernatural being as was forecasted in the paper was to consist of a man with an absolute or very wide knowledge of chemistry and an equally wide knowledge of engineering, then obviously such a man could not exist, because to have a very wide knowledge of either subject required the whole of one man's lifetime. But surely, between the two limits, there was the possibility of the existence of a man who had devoted his time to so much of chemistry and to so much of engineering in the particular points where those two came in contact that he would be of value to both? At the present time the average engineer had to come in contact with an average chemist, and both of them spoke a language which neither understood. It was as though this country sent delegates to Russia to put affairs in order in Russia who had no knowledge of the Russian language and who spoke merely English. It was above all things necessary, as the authors said, that there should be two suitable men working together. In the art world two such suitable men had been found when Gilbert and Sullivan came together, but Gilbert and Sullivan combinations were exceedingly rare, and he was afraid that the co-operation which the authors desired had proved in practice to be equally rare. That there was some necessity felt for a man who had the right to the title of chemical-engineer was, he thought, shown by the fact that in America there was a separate Society of Chemical Engineers, with

a membership of about a thousand, and about 18 months ago Prof. Hinchley and a number of others had been influential in forming a group of the Society of Chemical Industry to be devoted primarily to the study of subjects coming under the heading of chemical engineering, and that group had now a membership of about 600. That in itself, he thought, was sufficient evidence that both the chemists and the engineers in this country realised that there was room for that composite creature who had a knowledge of both sides of the subject. One of the great failings in the education both of the chemist and of the engineer in this country was the inadequate attention which was paid to the subject of physics. He should think that nine problems out of ten, if not 99 out of 100 which met the chemical engineer, or the chemist, or the engineer in his capacity in relation to works had to deal with physical problems. It was the little problem of the dust which arose in a process which proved fatal to the action of that process in the end. Another process was worked out which introduced the necessity for filtration, and one finished off with a material which could not be filtered. It was a colloid, and one did not know how to filter it. An adequate study of the knowledge of that part of chemistry and physics known as physical chemistry had not received sufficient attention in the curriculum of this country.

The authors had referred to the desirability of scientific control, the use of CO_2 recorders, and the like. In the course of his work he had had to go through a very large number of electrical works, and works requiring boilers producing steam in large quantities, and in the bulk of them he had been able to find CO_2 recorders, having generally the appearance of a bottle of crusted port. They were the sort of things which were very pretty, and they looked very nice to start with; but the wise works-manager employed a junior chemist to take snap samples or an arrangement of a drum with water, to take an average sample of CO_2, and test it from time to time, and instead of relying on draught-gauges to find whether there were leaks in the flues, he took a determination of the CO_2 at the back of the bridge, at the entrance and at the back of the economiser, and calculated out what the leakage would be far better than any recorder could do even when it was new, far less when it was old.

One of the directions in which the Germans had exceeded us in the past in connection with works-management had been their utilisation of works-sheets, that was, keeping accurate records of processes, so that costs could be allocated. That was an aspect of the matter which had not been dealt with sufficiently in England.

On the point of the calorific value of fuel, the President had stated one of the main difficulties; but as a matter of fact a number of the large combines in the North of England, such as the Cotton Spinners, the Calico Printers, and so on, were buying their fuel on calorific value, and on the basis of the amount of water which was allowed to be present; but they were able to do that solely on account of the fact that they drew their supplies from a limited number of collieries with whom their contracts were made. On the other hand, the question as to the nature and fusibility of the ash was almost equally important in many cases with the heat-value of the coal.

The statement that the efficiency of a turbine dropped 1% for every 10° F. of superheat, he would hardly like to accept. He would point out that with steam at 150 lbs. boiler pressure which had a temperature of 365° F., supposing that were superheated up to 700°, which was about the maximum temperature that could be attained in ordinary practice, a steam saving of 33⅓% would be accounted for. He hardly thought that such a saving was likely. On the other hand, it was a well-known fact that one obtained about 1% efficiency for every inch of increase on the vacuum, and as a matter of fact the question of superheat was vastly more important in reciprocating engines than in turbine-engines.

A good deal had been said in the paper about the question of transfer of heat through field tubes and the like. He had received two months ago a condenser from a firm of chemical plant manufacturers for a certain operation, and as it was designed and put in it was just large enough for its job. By putting in a few baffle-plates, and making it so that it really was a counter-flow condenser, it was big enough for five units.

On the question of effluent, he would like to point out that a good many stones had been flung at the Government in past times owing to the obstinacy with which they had refused to allow effluent to flow into various streams and rivers. That obstinacy had led paper manufacturers and others to carry out researches which had led almost invariably to very great savings on the part of the people concerned. Had it not been for the fearful nuisance of the wood-sulphite pulp residue of Norway and Sweden, he questioned whether people would have bothered to have got the alcohol out of the pulp, and carried out the operations which led to the evaporation of the residue with the object of making glutens and so on, for briquetting.

The point of mutually intelligible phraseology was one of supreme importance in the desired co-operation. The average works-chemist could not put the facts concretely before the average

engineer, because neither of them spoke a language which the other understood, and it was desirable that some of the big and wealthy firms should give money or ought to be persuaded to give money to help various scientific institutions in the way of founding Chairs for the subject of chemical engineering. It had been frightfully neglected, and the pre-eminence of Germany in the organic chemical world was almost entirely due, not to her chemists, but to her chemical engineers.

Mr. H. V. Mitchell assured the authors of the paper of the deep interest which he had taken in it. He found himself very much in agreement with the view expressed by Dr. Ormandy that the evolution of that superman, the chemical engineer, had to be aimed at, because, when one came to think of it, a refinery or any petroleum installation has to be managed or mismanaged, and the manager had to be selected either from the chemical or the engineering side. Were the manager of a refinery not very well acquainted with the chemical considerations underlying the processes, he would be in a very awkward position, and at the same time he should be a well-qualified engineer. He (the speaker) often thought that if we in this country made the same distinctions that the Germans made between an apothecary and a chemist, and an engineer and an engine-driver, it would be helpful. It was very difficult for the scientific chemist at times to get the engineer to follow his views. He certainly thought that the petroleum engineer should be an especially broad-minded individual who could follow the reasoning of the chemist.

With regard to fuel weighing and measuring, he remembered one occasion where fuel had been somewhat promiscuously supplied to a lot of portable steam boilers used for pumping wells, some of which were highly productive and some not. As soon as accurate measurements began to be taken of what the fuel consumption was, and what the wells were producing, it was found that in some cases the boilers were actually consuming more crude oil than was coming up from the wells. With regard to CO_2 recorders, they were certainly very useful; but a careful eye on the appearance of the gases from the chimney was also a very useful thing. He had within his own experience known the fuel consumption of a bench of stills brought down as much as 33% by judicious alteration of the draught conditions. No doubt in many places much fuel was thus wasted.

The authors remarked "The chemist must carry out the research, and when a satisfactory method has been evolved, the engineer will co-operate to work out the most satisfactory plant to be employed on a large scale." If things were like that—and no doubt they were

in some places—everything would be very satisfactory, but it did not always happen. For instance, he could recall a case where dephlegmators were installed to deal with a petroleum containing a very high percentage of volatile constituents, merely because in some other part of the world, where the crude was entirely different, those dephlegmators had worked satisfactorily on the same throughput. The chemist could see that the installation of such dephlegmators was going to reduce the output of the bench by 50%, but nevertheless they were installed, and the output consequently fell.

With regard to fuel economy, he thought there was a lot of room for using the condenser water more than it was used, especially for some types of crude. Every crude oil was different from other crude oils, and special considerations came in; but where one had a lot of oils which had to be sent about from one place to another through pipes, and very often had high setting-points, it was common practice to put internal steam lines through those pipes, and then a good deal of waste of steam was quite inevitable, because one could not keep hundreds of joints all tight, especially when the supervision was native supervision. In that connection he thought Dr. Perkin would find that, although it was well known that a boiler working at the pressure for which it was designed to work, worked most economically for power-production, yet when it came to sending steam about through innumerable steam lines, for keeping things warm, low-pressure steam really paid, because where one could not altogether avoid leakage one lost so much by high pressure. There, again, however, he thought a lot could be done by running the condensers with a judicious amount of water, taking the water practically boiling from the condensers, having culverts, and so keeping pipes which had to be heated, immersed in hot water.

Mr. Wilson said with regard to the point of loss of heat in plants, he was afraid to show his colossal ignorance of the processes used in the distillation of petroleum, but as the paper had laid stress upon the heat losses in oil-producing plant he desired to ask why it was not possible to use Diesel engines for some part of the plant, as for instance, pumping on a pipe line system. He thought it was generally admitted that in the Diesel engine, one had the highest possible thermal efficiency that could be obtained from the use of liquid fuel in any engine.

With regard to the suggestion made as to the buying of fuel on the calorific basis, he thought that stage had already been reached, as anybody who tried to sell an oil distilled from the low temperature carbonisation of coal, such as tar oil, would immediately find that the first question asked, as to its calorific value.

With reference to the collaboration of the chemist and the engineer in the production of oil he was afraid he could not say very much, but as regards the point of view of the use of the oil, he might say that he had for a considerable number of years been engaged in the Diesel oil engine industry, and an instance of the advantage of having a chemist in the factory had come to his notice in the following way: It had been found that in a number of cases the high-pressure intercooler coil of the two-stage air compressor, which coil was of copper tube, wore out and burst, generally blowing away the side of the cast-iron water-jacket casing. As such accidents were undesirable, the engine-builders set to work to render this part of the engine as safe as possible by providing a large relief-valve on the water-jacket of the h.-p. intercooler. This action, however, was only tackling the effect, and not the cause. In due course it was found that the relief-valve did not save the situation when a coil burst, and the danger of a piece of the cast-iron casing striking the driver of the engine still existed. Accordingly a large vulcanised rubber diaphragm was embodied in the side of the water-jacket, so that when the coil burst, the rubber burst also, and relieved the pressure, which effectually cured the difficulty from the point of view of accident. Even then matters could not be said to be satisfactory, and it was not until the firm had the good fortune to attach to their staff a chemical engineer that they arrived at the real cause of the trouble. They got at the root of it by the chemist's examination of the lubricating oil, and he proved to demonstration that the cause lay with the lubricating oil then used. It was shown by analysis of the intercooler drainage that the high temperature and pressure in the high-pressure stage caused the oil to oxidise and form fatty acids. It was this acid which came over with the h.-p. air that had eaten away the copper tube, and made it so thin that it burst. The firm had been using an oil which from their point of view was a satisfactory one because it was obtainable at a reasonable price, but they never suspected its being the direct cause of the trouble until the chemist proved to them by the iodine test that it contained a large proportion of unsaturated hydrocarbon. That is to say, it was an oil of high specific gravity, and the carbon was by no means stable under the oxidising influence of the heated compressed air. The engine-builders then set to work to select a lubricating oil which had the lowest possible proportion of unstable carbon, and having got it, they cured the difficulty with regard to the breakdown of the air compressor.

The paper had been exceedingly interesting to him, but it dealt almost entirely with the production side of the oil, as its title

indicates. Perhaps at some later stage in the year some other member would take up the question of the use of the oil, for in that direction the chemist and the engineer, he felt sure, could work together quite as much as they could on the production side, and the subject seemed to offer a wide field for joint research.

Mr. Anfilogoff remarked that there was, and always would be, ample work for the highly-trained chemist and the highly-trained engineer in the oil industry. There were certain questions which could only be tackled and dealt with by those two highly-trained technical people. But there were also questions which were purely and simply in the province of the chemical engineer. Evidently neither of the authors was aware that there were a number of universities on the continent which for a long time past had had a faculty of chemical engineering. Even old-fashioned Russia had in the Imperial Russian Technical Institute the Engineer-Technologue, which was equivalent to the chemical engineer of Belgium and of America. If Prof. Hinchley was the pioneer in starting the education of the chemical engineer, all his (the speaker's) friends knew that it had been his fixed idea for the past 20 years, and he thought he had been almost nauseating his friends by bringing up the subject so often in his discussions with them. With regard to the chemical engineer in the oil industry, he had seen some plants which undoubtedly looked a chemist's job. He had also seen some plants which had delighted his eye when he had first seen them new. They had been so skilfully engineered that he had thought at last he had seen the ideal plant for the oil industry, only to learn that after a month or two all those beautiful pipes and joints and connections had had to be dismantled because they would not work. He was speaking of facts, and he thought there were many in the room who knew of similar instances. So far as economy was concerned, of course economy was the ideal to aim at in managing any oil works, or any other works for that matter; but he hoped that even the gentleman who was economically mad would not go to the length of introducing coils through which very hot cracked oil under pressure was being conducted through his boiler. As a works-manager he (the speaker) would not have a night's sleep if he thought anything like that was going on. He did not think there was an engineer in the room who would agree to anything like that being done. The boiler as such was not the department of the chemist, and he did not think the engineer would permit him to put his coils through there. He believed, however, Dr. Perkin only referred to an experimental plant, and not to a plant successfully worked on a commercial scale.

He quite agreed with the last portion of the paper where the authors considered that life was too short for the chemist to be his own engineer and the engineer his own chemist; but he thought the authors had not had the experience he had had on the works with the chemist and the engineer. The chemist, often the more academically trained man of the two, looked down upon the engineer as a "$\frac{1}{2}$" fitter, and the engineer looked down upon the highly trained academical chemist as a creator of stinks. When those two gentlemen were in a works there had to be some arbiter of peace between them. That could not possibly be the business manager. In order to judge between the two, presumably the business manager had to bring in the outside expert chemist, like Dr. Perkin, and the outside expert engineer, like Mr. Palmer, and so *ad infinitum* if those two gentlemen also disagreed. The chemical engineer absolutely had his place on every works where any industry was carried on in which both chemical and engineering skill was required. There was room for the chemical engineer in the petroleum industry, and if the chemical engineer became an entity in the petroleum industry, there would not be quite so many abortive processes planted on the market, and there would not be quite so much money wasted. He would like to mention one case in which he was called in to advise. There had been some trouble with some agitators. The vertical shaft had been wobbling, and the tooth of the pinion kept breaking. The horizontal shaft was also wobbling about, and the belts would not stay on. All sorts of stick-fasts had been tried. He had suggested an examination of the inside. It was an alkali mixer, which had been designed and constructed by a very reputable firm of engineers, but they had put in a brass bush in the footstep for the vertical shaft to run in, and the caustic soda had corroded it. A cast-iron bush was substituted, and the plant gave no further trouble. That works had had a very eminent chemist and also a very practical and highly educated engineer, but they had not come together, and probably, as Dr. Ormandy had said, they spoke in different languages, and the one could not understand the other. In connection with the utility of the chemical engineer, he would like to tell the meeting the following story. There had been a small picric acid works close to him, which had developed some trouble with their sulphuric acid regenerators. He had been asked if he could design some means to concentrate the sulphuric acid without having those occasional small explosions owing to decomposition of the picric acid which remained in solution in the weak sulphuric acid. He did so, and had sent the design along to the Ministry of Munitions, who were delighted with it and

had asked him to go up and explain it. He had found two or three gentlemen sitting at a table, one of whom had congratulated him on the design of the concentrator, and who had said "What we are most particularly pleased with is that apparently you have not used a single ounce of copper in the whole design of the plant." He had simply smiled, and the gentleman then went on to say "Because it is a metal we cannot now obtain." Then he nearly fell off his chair.

In cases like that the chemical engineer was really wanted, and that was why he agreed that in a petroleum refinery especially there was plenty of scope for the highly trained and skilled chemist, purely as such. There was plenty of scope for the highly skilled technical engineer, and on top of that if the Company who was running the refinery was not going to waste a lot of money in their plant, there was also scope and a necessity for the highly trained chemical engineer.

Mr. Gathorne Young congratulated the authors and the Institution on having raised this important subject, and hoped that the discussion initiated that night might be continued, and that more opinions of engineers might be heard as well as those of chemists and chemical engineers. He agreed with everything that had been said in regard to the outstanding importance of the question of the education of the British chemical engineer of the future. He could corroborate what Dr. Ormandy had said regarding the competition which this country will have to meet from our enemies on the other side of the North Sea. Just as the last 25 years had been notable in the history of the world for the marvellous advance of the German chemist, so the next 25 years he expected would see something equally remarkable in the advance of the German engineer. If this country was going to combat that, it had to start at once to educate a corps of chemical engineers who would be able to look after the interests of this country adequately. Prof. Hinchley had said that the pioneer in this country of the education of the chemical engineer had been the Battersea Polytechnic. With all respect he suggested that Prof. Hinchley was not quite correct. The first school of chemical engineering in this country had been started by Sir William Ramsay in the University College of London about the year 1886 or a little later. Prof. Hudson Beare taught the engineering subjects, and the lecturer on chemical technology was Mr. Watson Smith, a well known chemical engineer of that period. That school had unfortunately languished for lack of students, and died out about the year 1896. His reason for mentioning that was that a memorial to Sir William Ramsay had been promoted, and one of the two forms which it was proposed that that memorial should take was the

institution of a school of chemical engineering in University College, London. A fund was being raised at the present time, and as many of the members of the Institution might be in sympathy with it he thought he would like to mention it. The Treasurer of the fund was Prof. J. N. Collie, F.R.S., of University College, London.

Prof. Hinchley said he desired to make an explanation in regard to Mr. Gathorne Young's remarks. Prof. Watson Smith was a personal friend of his, and he had collaborated with him as a chemical engineer when Prof. Watson Smith had been a chemist. Prof. Watson Smith had never made any claim, and never pretended to be anything of an engineer or to know anything about engineering. He (the speaker) thought Prof. Watson Smith's course had been called "Applied Chemistry," and he thought Prof. Watson Smith's experience of alkali works in the North of England had justified him in teaching applied chemistry. But no knowledge of the subject was of any good unless it was quantitative. It was of no use talking about fixing coils in tanks unless one knew how to calculate the lengths and the principles upon which to do the thing. That kind of thing was chemical engineering. Whatever it was called previously, that was the kind of thing which was being referred to at the present time.

A further communication from **Mr. Mitchell** follows :—

It is, I feel sure, quite impossible to point to any other industry in which there is such scope, and such great need of close co-operation between the engineering and chemical elements as in that of petroleum technology. Unfortunately, there does exist only too often in the mind of the works engineer a kind of jealousy that a chemist has a tendency to trespass, and almost a pious horror of the so-called chemical engineer. This ghost must be laid ; and I want, in all fairness, to put in a good word or two for all three of these most useful components of the staff—namely the engineer, the chemist, and the chemical engineer. In order to do this I will make a digression *pour préciser les idées*. Let us consider the case of two violinists, each playing homophonically and in harmony with each other, and then the case of a single performer executing a work in double-stopping passages. The latter I will liken to the engineering-chemist, the former two to the engineer and the chemist respectively. Now the performance of the third artist has a distinct place and value in the scheme of things musical, and the other two performers *know* that perfectly well. He is not trespassing ; he is not by subtle camouflage pretending to be *them* ; there is a zest in *his* work which has a value and a beauty of its own. The chemical-engineer or chemical technologist should be a man of this

type, a *distinct* type, not a chemist pretending to be an engineer, nor an engineer pretending to be a chemist.

In this respect I would like to say how heartily I agree with the views so clearly expressed by Sir Boverton Redwood on the broadening of the basis of our educational system generally, and with the remarks of Dr. Ormandy on the physico-chemical aspect of many—if not indeed all—technological operations. The need for a thorough grounding in General Physics is universally felt. The older text-books of what we now call Physics, were text-books of Natural Philosophy—to my mind, a fine phrase. We want Natural Philosophers by the million, and given a rational educational system we might have them. I would not like to be biassed in either direction, and I do not think that I am, but I must risk saying that most of the chemists I know are Natural Philosophers with a leaning towards things chemical, whereas many of the engineers could not by any stretch of human sympathy, be called Natural Philosophers.

Intellectual companionship is the best of all good things, even when one is situated here at home in the midst of civilisation. But oil-fields are generally in places where there are no great libraries, museums, lectures, or entertainments, to set off against trying climatic conditions. It is there that the value of intellectual companionship can be gauged and appreciated, or the lack of it deplored. On this account the selection of men becomes a matter calling for the most careful discrimination, and should not be relegated, as sometimes happens, to untechnical people who do not know, from downright personal experience on the property, the kind of individual required.

Dealing now with some of the practical issues arising from the paper, and *à propos* the remarks of Dr. Ormandy, it is remarkable how many of the processes and operations of every-day refinery practice are really physico-chemical propositions, and how few could be called purely chemical. Distillations, with or without steam, with or without vacuum, and under varied conditions of fractionation and dephlegmation, involving more or less cracking, afford great scope for the physical chemist. Decolorisation methods, such as those involving the use of bauxite, earths, or char, are of course matters of adsorption—quite physical: and even in the sulphuric acid treatment, the action is by no means entirely chemical. The acid decolorising process is not limited to the petroleum industry.

In washing such things as chloroform by the agency of sulphuric acid, the physico-chemical character of the action is equally

apparent. The mechanism of this remarkable decolorising process has never, I believe, been fully elucidated; but one thing at least is certain; it is a beautiful illustration of chemical and physical changes working in conjunction. I cannot imagine a physical-chemist watching the action of sulphuric acid upon similar cuts from different crudes, or upon different cuts from any particular crude, without becoming quite enthusiastic. Here we have a downright chemical action of carbonising nature induced between the acid and some of the more susceptible hydrocarbons, with the production of tarry and carbonised particles which absorb the colouring matters of the bulk; possibly the more readily, because they may, in a sense, be regarded as in a nascent condition. On the wax side of the refinery, the physical nature of the operations is quite as fully exemplified.

The refrigeration, pressing and sweating stages are purely physical in nature. The very production of cold itself, dependent upon the liquefaction and expansion of ammonia or carbon-dioxide gases, the physical chemist may be permitted to discuss. I well remember an occasion when for a long time a twenty-ton refrigerating unit made itself quite notorious by doing almost everything, except produce ice. I mentioned the critical temperature and other physical characteristics of ammonia gas to the engineer, and I fancy at first he thought I had got a touch of the sun. However, in the end he became sufficiently enthused to borrow from me a treatise on the Phase Rule. I am happy to say that shortly afterwards we got some ice produced, albeit not very much.

Another point of importance in a physical sense, although no part of the process work, is the lightning-protection of storage-tanks of volatile crudes and products. This is a matter upon which the engineers hold very diverse views, most of them distinctly entertaining. But after seeing tanks "protected" by a couple of more or less corroded high-resistance barbed-iron wires, beautifully earthed, I must confess to becoming quite meditative, and given to wondering what really *would* happen; finally consoling myself with the thought that a wide creek separated my house from the latest scientific improvements!

In conclusion I would say that in general, although, as must be expected, here and there things may go somewhat wrong, there is always a great deal that is going right. And to come back to the original contention, this happens when the chemists and engineers mutually help in a broad spirit of companionship, under the leadership of a manager who is a chemical engineer, and a man who can gauge the value of his assistants, and use them to the best advantage.

Dr. Perkin, in reply, held that all chemists should have a certain amount of engineering training, but they were chemists first, and their engineering training simply was that they could speak in words which the engineer would understand; and the engineer should have so much chemistry training that he could converse with the chemist who required his help from the engineering side. There were many cases, with the present training of the engineer and with the present training of the chemist, in which there must be a go-between such as was suggested by Prof. Hinchley. If he (Dr. Perkin) wanted a condensing coil, he would not calculate the necessary surface himself, but he would get Mr. Palmer to calculate it, stating the specific heat, boiling point, etc., of the material to be condensed. Generally speaking, he had found no great difficulty in getting the engineer to give him exactly the services required. With regard to superheat, the figures given were a close approximation to practice. Thus the Manchester Steam Users Association says "that every 10° F. of superheat will lower the steam consumption in an engine or turbine by about 1 % is commonly accepted as a rough approximation." Though it might be assumed that every B.T.U. passed into an engine in the form of superheat was convertible into work in the engine, the resultant economy of 10° increase of temperature was obviously a varying amount in each individual case both theoretically and practically. The practical result, however, in some cases exceeded the theoretical (if the latter be simply calculated), viz. where the initial condensation with saturated steam was large, as in the case of an engine lightly loaded for its capacity. On the other hand the economy actually obtained by 10° superheat in the case of a well-loaded engine may barely equal the (simply calculated) theoretical saving.

In reply to Mr. J. C. Templeton, a completely separate training of the chemist and engineer was not advocated, but repudiated. The chemist should have some engineering knowledge, and the engineer some chemical training. These two men could then work in close collaboration, and each be able to help the other.

As Mr. Mitchell maintains, low-pressure steam may be more economical for certain work, because there is less likelihood of leaking joints. For the same reason, and for fuel economy, exhaust steam should be used wherever possible.

Mr. Palmer said, in reply to Mr. Wilson, that there was no reason why the Diesel engine should not be used for Central Station Works in providing power for electrical plant and driving pumps, and possibly in many instances considerable economy would be effected thereby.

INDEX.

Ahwaz, Persia, 15–20.
Alcohol, 41–47.
Ammonia, 77, 81, 97, 99.
Antilogoff, N. A., on chemical engineering of petroleum, 306.

Barringer, H., on drilling bits, 214.
Benzol, 47, 84, 95.
Bibliography of paraffin wax, 128–130.
Black, Sir F. W., Toast of "Guests" at Annual Dinner, 230.
——, Presidential Address, War Problems of Petroleum Supply, 251.
——, chemical engineering in the petroleum industry, 294.
Blackler, M. B., on motor fuel, 62
Blast-furnace oils, 90.
Brame, J. S. S., on oil from mineral sources, 93.
British Empire, oil resources, 148.
Brown, W., on financing oilfields, 153.
Burford, J. W., on electrical power in oilfields, 137.
Busk, H. G., on Persian oilfields, 3–33.

Calorific values, 295, 302.
Campbell, A., on paraffin wax manufacture, 106–136.
Capital invested in oil, 147.
Carbonisation of coal, etc., 290.
Carter, A., on percussion drilling, 161–221.
Coal-distillation, 75–78, 82–85, 290.
Coal-oil, 94, 291.
Coal-powder, 295.
Coal-tar oils, 90.
Cowdray, Viscount, origin of trans-Scotland pipe-line, 239.
Craig, E. H. C., on Persian oilfields, 32.
Crisp, Sir Frank, obituary notice no. 19, p. vi.

Dalton, W. H., on technical investigation, 1.
——, on relative importance of seepages, 70.
——, on indexing, 73.
——, on the late Sir Boverton Redwood, 241.
Diesel engine, thermal efficiency, 304.
Dinner-speeches (1st Annual), 221–240.
Double-bottomed ships for oil, 238.
Drillers, temperament important, 215, 220.
Drilling, percussion systems, 161–221
Dunstan, A. E., on oil from mineral sources, 95.
——, on paraffin wax, 134.

Effluent problem, stimulates invention, 302.
Electrical power in oilfields, 137.
Evans, E. A., on unsaturated hydrocarbons, 135.
Expert advice in oil matters, 146, 155, 158.

Fell, D., on financing oilfields, 155.
Financing oilfields, 141–160.
Fishing experts, 220.
Fishing tools, 188.
Fishing with electromagnets, 215.
Formolite reaction, 121.
Fuel-economy, 286, 297, 301, 303, 304.
Future of the oil industry, 150.

Gasoline from natural gas, 292.
Greenway, C., on motor fuel, 56–60.
——, on oil from mineral sources, 93.
——, acknowledges toast of "Institution" at Annual Dinner, 227.
——, Valedictory Address, 249.
Grey, R. B., on electric weld of casing, 217.

Heat exchange, 288.
Henderson, J. A. L., on drilling systems, 215.
Hinchley, Prof. J. W., on chemical engineering of petroleum, 298, 309.

Illing, V. C., on Persian oilfields, 28.

James, S. L., on Persian oilfields, 26.
Jars in drill-gear, 163.

Lignite, 85, 99.
Lomax, E. L., on paraffin wax refining, 132.
Low-temperature carbonisation, 75–78, 82–85, 91–98, 290, 294.
Lubricating oil acidity, 305.

MacDougall, A., on financing oilfields, 154.
——, on magnetic fishing tools, 215.

Macrorie, B. F. N., on Persian oilfields, 139.
Manfield, W. H., on shale oil, 101.
May, H., on drillers, 215.
Mayo, H. T., on Persian oilfields, 3–33.
Medicinal petroleum, 159.
Millar, A., on drilling plant, 218.
Milne, Alexander, obituary notice, no. 18, p. vi.
Mitchell, H. V., on paraffin wax treatment, 133.
——, on chemical engineering of petroleum, 303, 309.
Montan wax, 86, 100.
Motor fuel, 33–69.
Moulton, Lord, Toast of "The Institution" at Annual Dinner, 222.

Ockenden, M. A., on percussion-drilling, 161–221.
Oilfields, electrical power in, 137.
——, financing, 141.
Oil-Fuel in British Navy, 234, 236.
Oil-shale distillation, 78–81, 291.
Oil wells, percussion drilling, 161–221.
Ormandy, W. R., on motor fuel, 33–69.
——, on oil from mineral sources, 99–105.
——, on financing oilfields, 156.
——, on chemical engineering of petroleum, 300.
Oxidation of paraffins, 135.

Palmer, T. C., The chemist and engineer in relation to the petroleum industry, 285–312.
Paraffin wax, manufacture, 106–136.
Peat, 86.
Percussion-drilling, 161–221.
Perkin, F. M., on oil from mineral sources, 75–105.
——, The chemist and engineer in relation to the petroleum industry, 285–312.
Persian oilfields, 3–33, 139.
Petrol-substitutes, 39–51.
Phenols in coal oils, 94.
Pipe-line across Scotland, 231, 239.
Producer tar oils, 90.
Promoters, 143–146, 155.

Qishm, Persia, 20–23.

Redwood, Sir Boverton, on Persian oilfields, 31.
Redwood, Sir Boverton, on motor fuel, 60.
——, on oil from mineral sources, 97.
——, on paraffin wax manufacture, 131.
——, on financing oilfields, 152.
——, on the Presidential Address, 283.
——, on chemical engineering of petroleum, 296.
—— (obituary notice), 241.
Refining made oils, 82.
Rosenplaenter, C. B., on cable drilling, 216.

Scotland, Clyde-Forth pipe-line, 231, 239.
Scurf (carbon) in retorts, 77, 105.
Seepages, relative importance, 70.
Shale-distillation, 78–81, 291.
Shale-oil, 40, 101, 294.
Specifications for drilling-plant, 193–213.
State relations to petroleum, 153.
Sulphur elimination from shale oil, 294.
Summers, M., on financing oilfields, 141–160.
Sunlight action on paraffin, 120, 135.
Sweating paraffin-scale, 122–126, 132.

Technical investigation, 1.
Technological scholarships, 2.
—— education, 228, 301, 308.
Terminology of drilling, 192, 215, 221.
Thompson, A. B., on oil from mineral sources, 102.
Thomsen, T. C., on motor fuel, 64.
Tothill, Sir Hugh H. D., acknowledges toast of "Guests" at Annual Dinner, 235.

Unsaturated hydrocarbons, 121, 135, 294.

War Problems of Petroleum Supply, 251–285.
Whitman, A. D., on fishing, 220.
——, on terminology of plant, 221.
Wilson, A. J., on chemical engineering of petroleum, 304.
Wilson, W. J., on paraffin wax manufacture, 106–136.
World's Production of Oil, 148.

Young, Gathorne, on technological education, 308.